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**MASTER's THESIS – Natural Resources Management and Development**

TH Köln - University of Applied Sciences

ITT- Institute for Technology and Resources Management in the Tropics and Subtropics

# **Perception of Climate Change and Soil Ecosystem-Based Adaptation Practices in the Northwest Region of Rio de Janeiro State, Brazil**

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## **Natural Resources Management and Development**

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# **“Perception of Climate Change and Soil Ecosystem-Based Adaptation Practices in the Northwest Region of Rio de Janeiro State, Brazil”**

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## **Abstract**

The material published by the Intergovernmental Panel on Climate Change (IPCC) clearly demonstrate the global trends in climate change. Impacts on the quality of livelihood due to raising temperature and frequent extreme events demand adaptation, as these conditions will likely worsen in the future.

The objective of this study was to evaluate at the local level the perception of smallholder farmers to climate change. Also, part of the study was to identify their measures to adapt, that include the preservation and mitigation of impacts on the regulating and provisioning soil ecosystem services, and their coping capacities to extended drought periods. The results of this study were analyzed in the regional and national contexts, thus identifying some gaps that need to be dealt with in order to ensure adaptation to climate change.

The study was conducted in two municipalities (Itaocara and Santo Antonio de Pádua). As in the findings for each municipality there were differences, the results cannot be used to generalize preparedness for drought and adaptation in the whole Northwestern region.

Overall, it is clear that local farmers adopt certain practices that are beneficial to the ecosystem (Ecosystem-based adaptation practices), but these measures are not sufficient to avoid losses during longer periods of droughts. Some of the practices need to be intensified or new ones have to be introduced so that they do not need to rely on coping capacities. Among the coping measures, farmers rely on their own personal finances when needed. Migration in the region occurs due to factors other than droughts resulting of climate change.

The lack of long-term adaptation practices might be attributed to lack of information, technical capacity and policies ensuring financial support for the adoption of long-term adaptation measures.

**Keywords:** Adaptation to Climate Change, Ecosystem- based Adaptation, Northwest of Rio de Janeiro, Drought

## Resumo

Documentos produzidos pelo IPCC – Painel Intergovernamental sobre Mudanças Climáticas evidenciam as tendências globais de mudanças climáticas. Impactos na qualidade de vida devido ao aumento de temperatura a frequência em eventos extremos demandam adaptação, já que essas condições tendem a piorar no futuro.

O objetivo deste estudo foi avaliar, em nível local, a percepção de pequenos produtores rurais às mudanças climáticas. Adicionalmente, parte da investigação foi identificar quais são as medidas adotadas para se adaptarem e que incluem a preservação e mitigação de impactos sobre os serviços ecossistêmicos de regulação e suporte de solos, e as medidas de controle imediatas a eventos inesperados de secas. Os resultados desta avaliação foram analisados dentro do contexto regional e nacional, assim identificando algumas falhas que necessitam ser trabalhadas para garantir a adaptação a mudanças climáticas.

Este estudo foi conduzido em dois municípios (Itaocara e Santo Antonio de Pádua), na região noroeste do estado do Rio de Janeiro. Os dados obtidos, em alguns casos, demonstraram diferenças, e portanto os resultados desta análise não podem ser usados para generalizar a adaptação e preparo para estiagens na região noroeste toda.

Em geral, é nítido que os produtores adotam medidas que são benéficas ao ecossistema (Adaptação baseada em Ecossistemas- AbE) mas estas não são suficientes para evitar perdas durante as estiagens. Algumas das práticas precisam ser intensificadas ou outras novas devem ser introduzidas. Assim produtores não precisariam depender de outras formas de resposta imediata em eventos de estiagens prolongadas. Entre as formas de resposta imediata, produtores dependem de recursos financeiros próprios quando necessário. Migração, quando ocorre, tem outros motivos que não são relacionados com mudanças climáticas.

A falta de medidas de adaptação a estiagens prolongadas pode ser atribuída a falta de informação, capacitação técnica e políticas públicas que asseguram suporte financeiro para a adoção de medidas de adaptação de longo prazo.

**Palavras-chave:** Adaptação a Mudanças Climáticas, Adaptação baseada em Ecossistemas, Noroeste do Rio de Janeiro, Secas.

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## List of Abbreviations

<b>AbE</b>	Adaptação baseada em ecossistemas
<b>ABC Plan</b>	Low Carbon Agriculture Plan (Plano de Agricultura de Baixo Carbono)
<b>AC</b>	Adaptive Capacity
<b>CAR</b>	Cadastro Ambiental Rural (Rural Environmental Register, defined through the National Forest Code)
<b>CBD</b>	Convention on Biological Diversity
<b>CEMADEN</b>	Centro Nacional de Monitoramento e Alerta de Desastres Naturais (Brazilian Centre for Natural Disaster Monitoring and Alert)
<b>EbA</b>	Ecosystem-based Adaptation
<b>EMATER-Rio</b>	Empresa de Assistência Técnica e Extensão Rural no Estado do Rio de Janeiro (Rural Extension and Technical Assistance in the Rio de Janeiro State)
<b>EMBRAPA</b>	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
<b>ES</b>	Ecosystem Service
<b>FAO</b>	Food and Agriculture Organization of the United Nations
<b>FIOCRUZ</b>	Fundação Oswaldo Cruz (Oswaldo Cruz Foundation)
<b>GDP</b>	Gross Domestic Product
<b>GHG Emissions</b>	Greenhouse Gas emissions
<b>ha</b>	Hectare/hectares
<b>IBGE</b>	Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics)
<b>INCRA</b>	Instituto Nacional de Colonização e Reforma Agrária (Brazilian National Instituto for Colonization and Land Reform)
<b>INMET</b>	Instituto Nacional de Meteorologia (Brazilian National Meteorological Institute)
<b>INEA</b>	Instituto Estadual do Ambiente (Rio de Janeiro State Environmental Institute)
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IUCN</b>	International Union for Conservation of Nature
<b>IVDNS</b>	Índice de Vulnerabilidade aos Desastres Naturais Relacionados às Secas no Contexto da Mudança do Clima (Vulnerability index to natural disasters related to drought in the context of climate change)
<b>MMA</b>	Ministério do Meio Ambiente (Brazilian Environmental Ministry)

<b>NAP</b>	National Adaptation Plan
<b>NDC</b>	Nationally Determined Contributions
<b>NGO</b>	Non-governmental organization
<b>NOAA</b>	National Oceanic and Atmospheric Administration
<b>PNA</b>	Plano Nacional de Adaptação à Mudança do Clima (Brazilian National Adaptation Plan to Climate Change)
<b>SEA</b>	Secretaria do Estado do Ambiente (Rio de Janeiro State Environmental Secretary)
<b>SEAPPA</b>	Secretaria do Estado de Agricultura, Pecuária, Pesca e Abastecimento (Secretary of Agriculture, Livestock, Food Supply, and Fisheries of the State of Rio de Janeiro)
<b>UNCCD</b>	United Nations Convention to Combat Desertification
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>UNISDR</b>	United Nations Office for Disaster Risk Reduction
<b>US\$</b>	US Dollar
<b>WWF</b>	World Wildlife Fund for Nature

# 1. Introduction

In the 13<sup>th</sup> Edition of the Global Risks Report<sup>1</sup>, published in 2018, extreme weather events, natural disasters and failure of climate change mitigation and adaptation are cited among the top five risks both in terms of likelihood and of environmental impacts. Though the risk analysis of the report considers the economic aspect in term of impacts and losses, it does not fail to mention the interconnection between the environmental aspect with the economic, geopolitical, societal and technological ones. Changes in climate are globally perceived. According to the IPCC's Climate Change Synthesis Report (IPCC, 2014), since the 1950s the climate system is warming up and related to the observed changes in the environment, such as the sea level rise and reduction of ice and snow. Not only the pattern of dry and wet seasons is changing but also the severity and frequency of extreme events such as cyclones, floods and heatwaves. Climate change affects the distribution of rainfall and leads to more extreme weather events, causing more floods and droughts (Chang and Bonnette, 2016).

Therefore, mitigation and adaptation strategies to climate change are needed. As stated in the IPCC Synthesis Report, as climate change worsens, challenges in adaptation will rise. Hence, "adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change" (IPCC, 2014, p.76). Risks of impacts due to climate change can be reduced, though they will still be impacts.

The Northwest area of Rio de Janeiro state has, in theory, a defined wet and dry season throughout the year. However, in 2014 and again in 2017, the dry season was unusually longer, which caused disruptions in the local agricultural economy. When analyzing the precipitation patterns of the period between 2012 and 2017, these changes are visible and so is the perception of smallholder farmers that the temperature has been on the rise and precipitations levels have been lower than before. This fact supports the affirmation in the IPCC's Summary for Policymakers (IPCC, 2012), that the overall increase in the number of warm days and nights in global scale is very likely to happen. The same publication also mentions the importance of effective risk management involving actions to reduce and transfer risk. Also, it needs to be emphasized the importance of the monitoring, research, evaluation, learning and innovation in the process of building up adaptive capacity. These key elements help avoiding reaching the limits to adaptation.

For Klein et al. (2014), limit to adaptation is when there is no alternative for adaptation or the effort to reach it is too far too great in order to keep the sustainability of the environment. Such situation leads to loss and damage. Warner et al. (2013, p.10) define loss and damage as "the inability to respond adequately to climate stressors." The question that remains is to what extent households are capable to deal with climate change in order to avoid loss and damage due to maladaptation. However, the authors argue that the capacities to adapt vary

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<sup>1</sup> Published by the World Economic Forum. Available at:  
[http://www3.weforum.org/docs/WEF\\_GRR18\\_Report.pdf](http://www3.weforum.org/docs/WEF_GRR18_Report.pdf) (Accessed 10 February 2018)

from region to region and sector to sector, which makes it difficult to measure and compare these capacities.

For Chantararat (2015), the increase in climate variability and in the occurrence of extreme weather events can put pressure on the need for more powerful climate risk financing scheme. Warner et al. (2012) add to the need of climate financing, that it is necessary to understand how the climate, among other variables such as food security, can also influence the decision of migration. By doing so, adaptation investments can be better and more efficiently planned. Therefore, considerations in regard to migration due to changes in the climate are important, particularly due to the fact that it may trap poor communities in the poverty cycle.

As drought affects the hydrological ecosystem services such as the supply of water, it also affects the riparian and wetland ecosystems, as they also need water for the services they provide (Banerjee, 2013). Therefore, there is a cascade effect in which many ecosystem services end up being affected in the event of drought. However, of the several studies describing and valuing ecosystem services, soil natural capital is often left aside (Dominati et al., 2010). As soils provide the regulating services in enabling crop diversification and erosion control and the supporting services of food livestock production (FAO, n.a), it is clear their importance and need to increase resilience of these services in the event of drought.

Considering the limitations of smallholder farmers in developing countries, in ensuring adaptation to climate change, a direct form of ensuring their livelihoods is to help them adopt farming practices based on the ecosystem services (van Noordwijk et al., 2011 in Vignola et al., 2015). Ecosystem-based Adaptation (EbA) ensures not only the benefits of adaptation to climate change, but it also helps the conservation of biodiversity and strengthens economic resilience to farmers and consequently enhances local economies (Rizvi et al., 2015).

The purpose of this study was to analyze the perception of climate change among smallholder farmers in the Northwest area of Rio de Janeiro State, taking as basis the information from two municipalities, Itaocara and Santo Antonio de Pádua, their Ecosystem-based Adaptation measures due to impacts of droughts in the soil ecosystem services (particularly in the provisioning and regulating services) their coping measures resulting from maladaptation to climate change and what the limit to adaptation to these climate changes are. This investigation also aimed at looking at individual finance mechanisms and migration, and whether they are coping mechanisms or adaptation mechanisms to the regional climate change.

## 1.1 Problem Analysis

According to the Annual Report of Natural Disasters (2014), 4,433 municipalities in Brazil were hit by natural disasters, and out of this number, 71% were due to droughts or dry spells (IVDNS, 2017). In analyzing precipitation trends in the southeast coast of Brazil, Zilli et al. (2017) concluded that the negative trends in the percentage of rainy days in the north of

Rio de Janeiro State confirm the trend of alteration in precipitation patterns due to climate change identified by Dereczynski et al. (2013).

Rodriguez (2017), in assessing drought risk in Rio de Janeiro State, concluded that the Northern part of the state has the highest exposure to drought, and this exposure decreases when going towards south of the state. As the study was based primarily on secondary data, there is the need of evaluating the perception of climate change and drought risk in the areas.

In analyzing precipitation data collected officially in the municipality of Itaperuna by the INMET (approximately 85 km from Itaocara and 70 km from Santo Antonio de Pádua), in the period between 2012 and 2017, it is possible to observe abnormalities in the pattern and in the quantities. In Itaocara it was possible to obtain data on precipitation collected by a smallholder farmer and in Santo Antonio de Pádua the local prefecture also keeps track of precipitation measurements. These local measurements also demonstrate the abnormalities in precipitation, following the pattern officially registered in Itaperuna. The changes in the climate registered and analyzed in this thesis will be further discussed in the following sections.

## 1.2 Research Gaps

Although there is evidence to identify the risk of drought in both municipalities, as studied by Rodriguez (2017), little is known about the adaptation strategies adopted by the smallholder farmers. There is no secondary literature for the region that evidencing if there are adaptive strategies and if so, if these strategies strengthen long term resilience to climatic changes in the study area.

There is a general knowledge gap in the study area in regard to Ecosystem-based Adaptation (EbA) and measures to protect soil ecosystem services. Adaptation to climate change using biodiversity and ecosystem services is a win-win tool in which farmers and the ecosystem become more resilient to climate change. Farming practices to enhance productivity have been adopted in the last decade, thanks to the Rio Rural Program. Some of these practices might be also useful in supporting adaptation. And these are the practices that need to be identified in the municipalities of Itaocara and Santo Antonio de Pádua, so that future needs are better understood.

The Rio Rural - Sustainable Rural Development Program in the micro-basins of Rio de Janeiro State, funded by the World Bank and supported by the Food and Agriculture Organization of the United Nations (FAO), has been funding projects since 2009 that ensure the improvement of the small properties and enhance their productivity (Nehren et al., 2017).

Through this program, smallholder farmers have received financial support for measures such as the introduction of dripping-system irrigation and the protection of native vegetation and riparian forests. Among many of the adopted measures incentivized through the program, many not only ensured the improvement of the farming system, but also the

resilience to climate change. There is no secondary literature that reviews which of these adopted measures can be classified as EbA or as coping measures to deal with droughts in the municipalities.

The coping capacities of the local households, such as financial mechanisms for risk transfer or migration are also not identified. It is unknown what financial mechanisms are adopted at the individual level and whether migration is an alternative to smallholder farmers in times of or as result of the impacts of drought.

All the needed information pointed out as knowledge gap is fundamental, for example, for the evaluation of status implementation of the National Adaptation Plan (NAP) at the regional level. By acquiring the data in the proposed study area, it was possible to evaluate what may be some constraints for the implementation of the NAP at the local, state and even at the national level. It can also support the development of financial mechanisms to support rural households and policies related to regional migration when needed.

### 1.3 Research Questions

Based on the research gaps identified for the northwest region of Rio de Janeiro state, in particular the municipalities of Itaocara and Santo Antonio de Pádua, the following are the questions this investigation aimed to address:

- What changes in the climate have smallholder farmers perceived in recent years?
- What have they been doing to adapt to these changes?
- What alterations in provisioning and regulating soil ecosystem services have been noticed?
- What of the adopted measures are soil EbA measures that ensure the maintenance provisioning and regulating services of soils?
- What would be their limit to adaptation before leaving the rural area?

### 1.4 Objectives

Considering the problem analysis and the research gaps for the study area, the objective of this investigation is to analyze the perception of climate change and adaptation to climate change, in particular the soil ecosystem-based adaptation measures that ensures the maintenance of provisioning and regulating soil services.



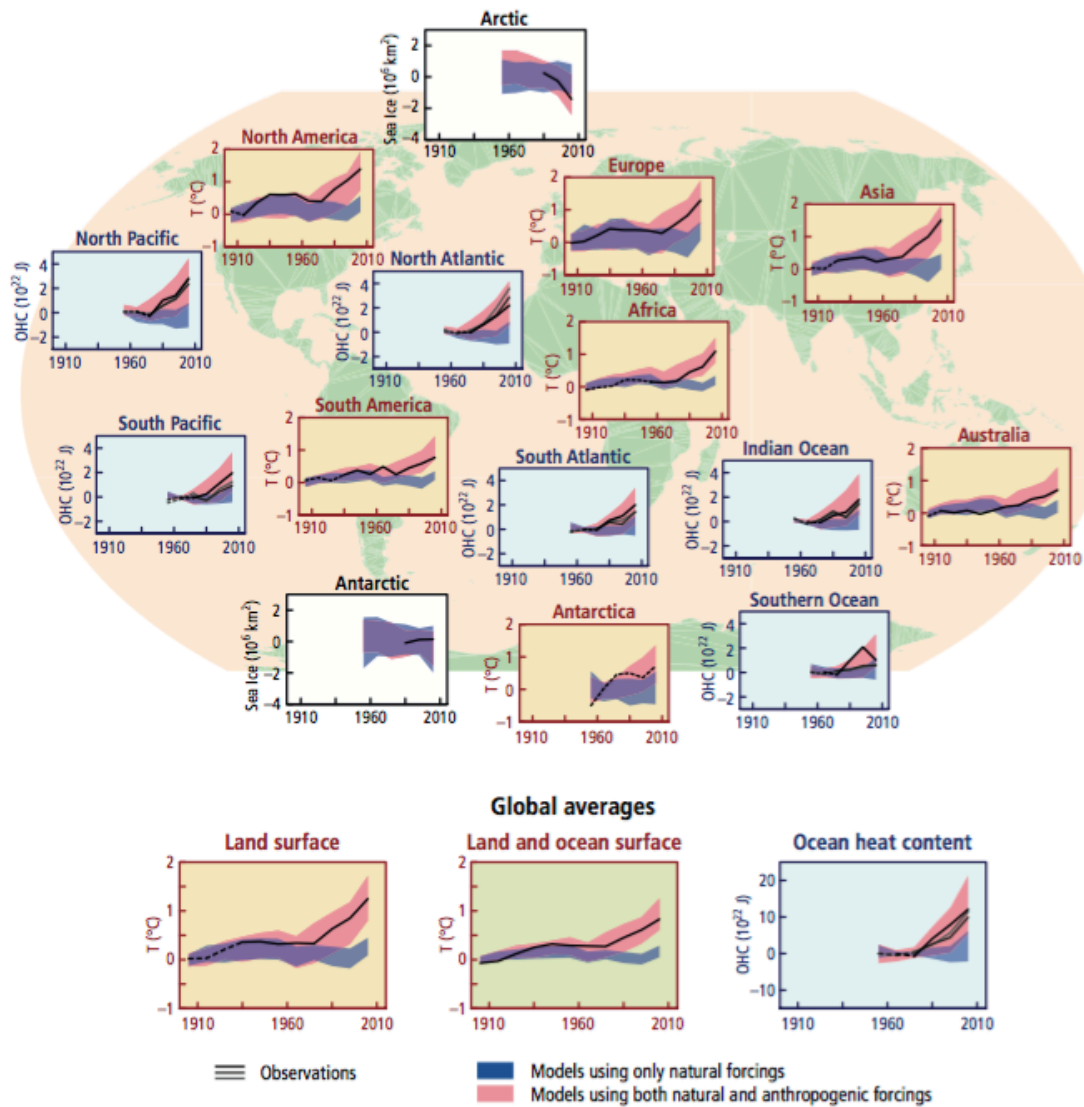
#### 1.4.1 Hypothesis

The three hypotheses to be tested in this investigation are:

1. Smallholder farmers perceive climate change, they have introduced adaptive measures to preserve the provisioning and regulating soil ecosystem services, not only due to these perceived changes but mainly due to the losses caused by the drought in 2014;
2. As they area adapted to these climatic changes, there has been little financial impact at the individual level since last drought occurred in 2017;
3. Migration, either temporary or permanent, is neither an adaptive measure nor a coping measure in case of drought.

## 2. Theoretical Framework

Changes in the precipitation pattern are expected to worsen as result of global warming. Chang and Bonnette (2016, p.1) affirm that “climate change may shift the distribution of rainfall events with more extreme events, which may lead to more frequent floods and drought.” The Synthesis Report of the IPCC Fifth Assessment Report (AR5; IPCC 2014) acknowledges that the Earth’s surface have been in each of the last 30-year period warmer than any decade before 1850. According to the same report, observed changes in the climate system follow the patterns of surface temperature increase of models using natural and anthropogenic influences in the climatic system, including the increase in emission of greenhouse gases.



**Figure 1:** Observed and Simulated Change in Earth’s Surface Temperature (Source: IPCC, 2014)

These changes in the surface temperature lead to higher risks and impacts. The Synthesis Report emphasizes the risk of food and water insecurity, causing loss of rural livelihood and

particular impact on poorer individuals. Another risk impact is on the availability and functions of ecosystem services. As one of the many impacts, the quality of ecosystem services - particularly of soil ecosystem services - has been altered.

Due to these alterations in the soil ecosystem services, adaptation to these changes is taking place, which includes the adoption of ecosystem-based adaptation practices, measures to cope with financial burdens, migration and institutional measures. Following is the state of art of information related to soil ecosystem services impacted due to drought caused by climatic changes and the ecosystem-based adaptation measures that can avert or minimize these impacts.

## 2.1 Climate Change and Drought in Brazil

The National Oceanic and Atmospheric Administration of the United States of America (NOAA) categorizes drought as an extreme event. According to the United Nations Office for Disaster Risk Reduction (UNISDR, 2009, p.8), drought is broadly defined as “a deficiency of precipitation over an extended period of time, usually a season or more, which results in a water shortage for some activity, group, or environmental sectors.” The IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC, 2012, p.167) defines drought as “a period of abnormally dry weather long enough to cause a serious hydrological imbalance.” The same publication also assures that “it is virtually certain that increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes will occur in the 21st century at the global scale.” (IPCC, 2012, p.13). Knowing that higher temperatures influence the soil moisture, the impact of drought is increased as higher air temperature can cause an increase in evaporative demand (IPCC, 2012, p.167).

In humanitarian terms, the International Federation of Red Cross and Red Crescent Society defines drought as a slow event that gradually increases its negative effects in a certain area<sup>2</sup>. It may result in other disasters such as food insecurity, epidemics, displacement and desertification.

The National Drought Mitigation Center of the University of Nebraska- Lincoln (NDMC)<sup>3</sup> USA states that the definition of drought depends of the region and disciplinary approaches in defining it. In its website, the NDMC presents the definition according to Wilhite and Glantz (1985). It is divided into four different categories, according to the measuring approaches. UNISDR also uses the same definitions:

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<sup>2</sup> Available at: <http://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/drought/> (Accessed 13 August 2018).

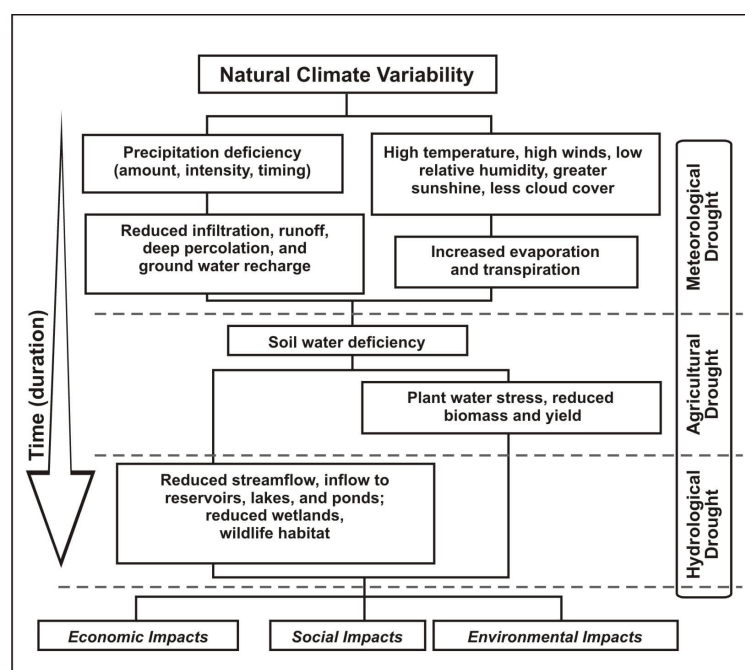
<sup>3</sup> Available at: <http://drought.unl.edu/DroughtBasics/TypesofDrought.aspx> (Accessed 28 May 2018).

*Meteorological drought:* Considering a limit of 50 percent of normal precipitation over a six-month time period, it varies from region to region.

*Agricultural drought:* It links information meteorological and hydrological information to measure impacts to agriculture due to lack of soil water. Therefore, there is no direct correlation between amount of precipitation and status of surface water availability. Agricultural drought is dependent of precipitation (quantity and intensity) and infiltration capacity, which varies according to the type of soil.

*Hydrological drought:* Generally defined by unusually low availability of surface and subsurface water supply. This category of drought affects activities which make direct use of surface water, such as irrigation, recreation and ecosystem management and environmental protection.

*Socio-economic drought:* It reflects the supply and demand of goods that are dependent of water supply and therefore dependent of weather. Considering the rising demand of supplies, the occurrence of drought tends to increase vulnerability.



**Figure 2:** The Different Categories of Drought and their Relationships (Source: NDMC)

The Brazilian National Annual Report on Natural Disasters cites drought as the event that most affected Brazilian municipalities in 2013. Though it is the natural event that socio-economically impacts the most, it is the one that least causes deaths in the country (in MMA, 2017).

According to the Annual Report of Natural Disasters from 2014, 4,433 municipalities in Brazil were hit by natural disasters, and out of this number, 71% were due to droughts or dry spells (MMA, 2017). In analyzing precipitation trends in the southeast coast of Brazil, Zilli et al. (2017) concluded that the negative trends in the percentage of rainy days in the

North of Rio de Janeiro State confirm the trend of alteration in precipitation patterns in the State of Rio de Janeiro due to global climate change, already identified by Dereczynski et al. (2013). Such situations of hydrological stress, that caused socio-economic impacts, could become regular in the future, as observed by Marengo (2009) in MMA (2017).

Rodriguez (2017), in assessing drought risk in the Rio de Janeiro State, concluded that the Northern part of the state has the highest exposure to drought, and this exposure rate decreases when going towards south of the state. The author concluded that the municipalities of Santo Antonio de Pádua and Itaocara both have a very high-risk degree of drought. In regard to vulnerability, the report on the Vulnerability Index to natural disasters related to drought due to climate change (IVDNS), produced by the World Wildlife Fund for Nature (WWF) and the Brazilian Ministry of Environment in 2017, analyzed vulnerability based on results of simulations of different climatic models. One analyzed model of precipitation variation (Eta-HadGEM) presents a high to very high coefficient of variation and the other (Eta-MIROC5) presents a low to very low coefficient. The report presents the vulnerability index for both municipalities in ranges of vulnerability from low to moderated vulnerability, based on the precipitation coefficient obtained through four different models. Though the variation of precipitation is high in the region, vulnerability is pointed out to be theoretically low.

## 2.2 Adaptation Policies and Measures to Adapt to Climate Change

According to the Synthesis Report of the IPCC Fifth Assessment Report (AR5), “both adaptation and mitigation can reduce and manage the risks of climate change impact” (IPCC, 2014, p.76).

The Cancun Adaptation Framework (2010) represented the milestone for adaptation in developing countries, by supporting these countries to produce their respective National Adaptation Plans (NAP) (Warner et al., 2013). The Conference of the Parties to the UNFCCC, in its 17<sup>th</sup> meeting in 2011, recognized the importance of the national adaptation planning for countries to assess their vulnerabilities and risks to climate change and address adaptive measures (UNFCCC, 2012).

Following the need of adaptation, the Brazilian National Ordinance 150, issued on 10. May 2010 instituted the Brazilian National Adaptation to Climate Change Plan (NAP). The Ordinance established that the National Plan would be implemented by the Federal Government with the cooperation of the states and municipalities.

The latest version of Brazil’s NAP was issued in 2016 and includes proposals to enhance resilience to climate change until 2020. One basic premise of the NAP for agriculture is to promote a legal framework that supports adaptation in agriculture under climatic changes. In order to attain the objective, it is clear that there is the necessity of identifying first what needs to be supported at the rural household level. By doing so, adaptation measures can be identified and implemented in order to enhance resilience to climate change.

### 2.2.1 The Brazilian National Adaptation Plan for Climate Change

The Brazilian National Adaptation Plan for Climate Change presents three specific objectives:

- Enhance and improve scientific and indigenous knowledge, in support of production, dissemination and management of information for the development of capacity building measures for governmental bodies and society;
- Coordination and cooperation among public bodies to improve climate-risk management action;
- Identify and propose measures for adaptation and minimization of climate risk.

Besides these three objectives, the NAP presents 11 thematic strategies for adaptation in different sectors considered key elements in ensuring economic development of the country. Among these sectors are agriculture, biodiversity conservation and natural disasters.

The strategies presented in the NAP are related to the vulnerabilities and weaknesses in each sector and the measures to tackle with these vulnerabilities as to ensure better resilience to the climatic changes. A general problem pointed out in the NAP is the lack of information and knowledge. Therefore, the prioritization of information about the climate and its impact is a high priority in the plan for all the economic sectors.

Among the various challenges, there is the implementation of risk transfer mechanisms such as financing mechanisms and insurance for loss and damage, building up resilience, the necessity of capacity building of technical personnel for better field support, and enhancing soil conservation practices to avert, minimize and prevent desertification.

The NAP also mentions building up resilience to climate change through the National Plan for the Reduction of Risks and Disasters (see section 2.2.2).

In regard to the strategy related to biodiversity conservation, the NAP cites the importance of EbA strategies to ensure resilience and biodiversity conservation. However, the plan admits the lack of knowledge in the basic concepts and therefore the need of developing implementation tools for the economic evaluation of EbA strategies. In this chapter of the NAP, related to biodiversity conservation, there is no specific plan for the conservation of management of soil ecosystem services or EbA strategies specifically focused on soil conservation.

The chapter dealing with risk and disaster management cites drought as the major disaster event in Northeast Brazil. In Southeast Brazil, the priority is to ensure resilience and immediate action in case of events such as floods and landslides. It mentions the necessity of implementing EbA measures to ensure resilience, the implementation of insurance schemes as immediate measures in case of losses and damage and the necessity of early warning systems; however, with a focus on rapid onset events and not for slow onset events such as drought.

According to the NAP First Monitoring and Evaluation Report for the implementation of actions related to the years 2016-2017, 100% of the specific objectives abovementioned

had actions implemented. Among these actions, the report cites the elaboration of the drought vulnerability mapping (IVDNS) and new climate scenario studies for the improvement of knowledge on future climate change scenarios.

In relation to the objectives in the agriculture sector, the report cites the successful generation of new climate monitoring systems for agricultural purposes.

### 2.2.2 Brazilian National Plan for Risk Management and Natural Disaster Response

The Brazilian National Plan for Risk Management and Natural Disaster Response<sup>4</sup> was launched in 2012 with the aim of investing in grey infrastructure and emergency infrastructure for the response of natural disasters of rapid nature, such as floods and landslides. The plan also foresaw the creation of the CEMADEN - National Center for Monitoring and Alert to Natural Disasters<sup>5</sup>. In the plan, measures to mitigate or respond to drought are not mentioned.

### 2.2.3 Adaptation Policies and Measures in the State of Rio de Janeiro

The State of Rio de Janeiro has acknowledged climate change impacts and therefore taken actions to tackle the issue. In 2017, through the State Decree 45,892, the Rio de Janeiro State government established the committee for the creation of the State Plan for the Mitigation and Adaptation to Climate Change for the consolidation of a low carbon agricultural economy (Plano ABC). The Plan was launched in March 2018 and the objectives are: the reduction of GHG emissions; enhancing food security and strengthen resilience to climate change through the adoption of technologies for sustainable production in the state's agricultural sector. The State plan is one of the 24 launched plans cited in the NAP First Monitoring and Evaluation report.

According to the plan, the public policies and governmental program established for the mitigation and adaptation to climate change are:

- State Program for the Rural Sustainable Development (Rio Rural Program): Funded by the World Bank and supported by the Food and Agriculture Organization of the United

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<sup>4</sup> Plano Nacional de Gestão de Riscos e Respostas a Desastres Naturais. Available at: [https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwjojuHxobXdAhULL1AKHcKVA0QFjABegQICRAC&url=http%3A%2F%2Fwww.planejamento.gov.br%2Fapresentacoes%2Fapresentacoes-2012%2F120808\\_plano\\_nac\\_risco\\_2.pdf&usg=AOvVaw0z5vJUT26FTw6Op1ES7dHI](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwjojuHxobXdAhULL1AKHcKVA0QFjABegQICRAC&url=http%3A%2F%2Fwww.planejamento.gov.br%2Fapresentacoes%2Fapresentacoes-2012%2F120808_plano_nac_risco_2.pdf&usg=AOvVaw0z5vJUT26FTw6Op1ES7dHI) (Accessed 12 July 2018).

<sup>5</sup> The Center is a multidisciplinary institution for the monitoring, alert, prevention and reduction of impacts through the modelling of monitoring information for the prediction of extreme events. According to Nobre (personal communication, July 2018), the Center deals only with the monitoring and prediction of rapid onset events such as storms, floods and landslides.

Nations (FAO) and several other NGOs and rural organizations. The objective of the program is to enable the improvement of rural life quality through the use of technologies and techniques that ensure the sustainable use and conservation of natural resources. The program is foreseen to end in 2018 after investing US\$ 153 million in different projects that contribute to the sustainable development of agricultural practices in rural areas.

- Climate Change State Plan: In 2010, the State Law 5690 established the Climate Change State Plan, which was regulated in 2011 through the State Decree number 43216. This plan aims the establishment of the development of the state based on low carbon emissions and the adaptation to climate change impacts. Among measures related to adaptation to climate change, one is related to the increase in the number of projects financed through the Rio Rural program.

- State Action Plan for Adaptation to Climate Change: The objective of the State Plan is to ensure that other state program such as the program for the conservation of native forests, water and of environmental compensation for losses and damages caused by private parties, are implemented. By ensuring the efficiency of such programs, the mitigation of impacts caused by climatic changes and the promotion of adaptive measures are also ensured.

- Rio de Janeiro State Greenhouse Gas (GHG) Emissions Inventory: The State promoted in the years 2005, 2010 and 2015 the compilation of GHG emissions for each economic sector. Therefore, it has enabled the state to identify the main source of emissions and thus come up with measures to reduce them. These inventories have helped identify that the main source of GHG emissions come from animal husbandry (cattle raising) and other agricultural activities.

### 2.3 Soil Ecosystem Services and Drought

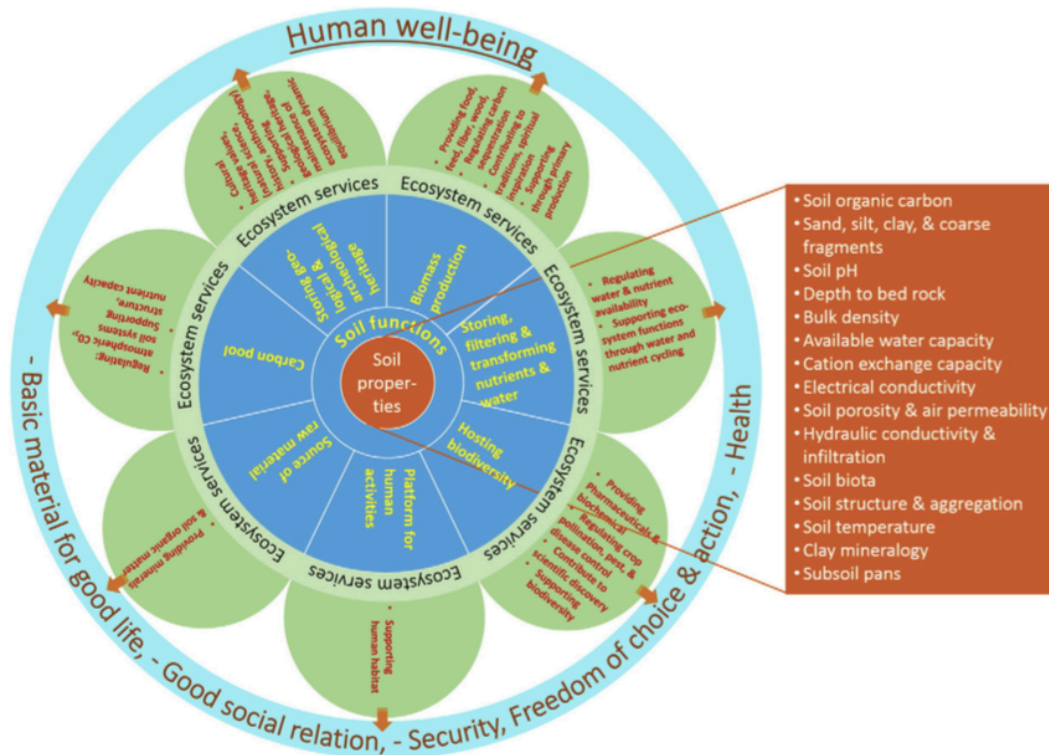
Walker et al. (2004; cited from Kinzig et al. 2006), define resilience as “the capacity of a system to absorb disturbance and re-organize while undergoing change.” Therefore, adaptation is a matter of improving resilience. However, importance has to be given to the ecosystem same time ensuring livelihood to rural households. Kinzig et al. (2006) analyzed ecological thresholds and their interactions in case of drought in a water basin in Australia. The authors defend the importance of valuing ecosystems services as to ensure that the ecological systems remain resilient to changes, such as shifts in precipitation patterns.

Anjos and Pereira (2013) argue that soil can be defined according to its use. For a geologist or civil engineer, it may be the material coating rocks, but for the agronomists, soil is the superficial Earth covering, made up of mineral and organic material, water and air retention capacity and thus with the capability of supporting plant growth.

These are some of the benefits from soil systems. Benefits that are obtained from the ecosystem are called ecosystem services (Comerford et al., 2013). According to the Millennium Ecosystem Assessment (2005), ecosystems provide a number of services and goods divided into four categories: provisioning services, regulating services, cultural



services and supporting services. Bayeve et al. (2016) state that soil ecosystem services have become more important in recent years, as international agencies and governments began to see these services of importance due to its natural capital. Additionally, Adhikari and Hartemink (2016) note that soil properties and use influence the provision of ecosystem services.

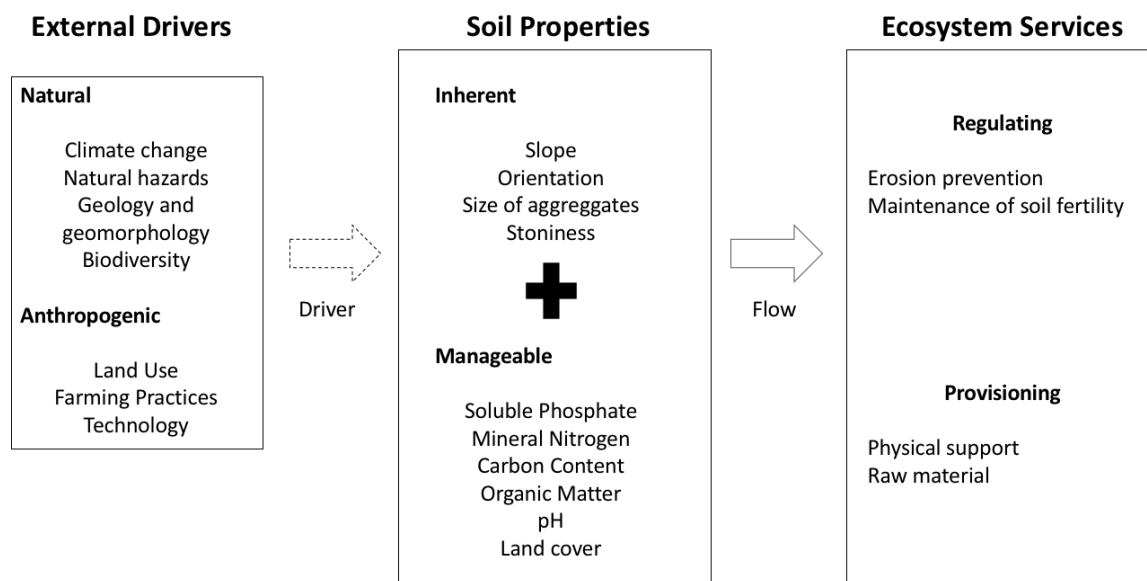


**Figure 3:** Conceptual Diagram Linking Soil Ecosystem Services through Functions and the Well-Being of Humans (Source: Adhikari and Hartemink, 2016)

In reviewing pertinent literature regarding soils and ecosystem services, Adhikari and Hartemink (2016) concluded that most publications try to demonstrate how soil is linked to the flow of ecosystem services. Thus, the valuation of soil ecosystem services is often made through the change in the values in soil productivity, or specifically through crop production.

Among different roles of soil in the provision of services, Dominati et al. (2010) highlight its fertility and structural roles. The cycle of soil nutrients ensures the fertility of soils which is necessary for plant growth. Comerford et al. (2013) define the provisioning services as products from soil or when it is used for the production of other products. Examples of these services are the use of soil components for concrete and brick manufacture and worms and microbes in providing conditions for plant growth. They define the regulating service provided by soils as services that “control the processes of water flow, nutrient uptake and release, carbon transfer, and chemical processing” (Comerford et al., 2013, p.3). Examples of these services are water regulation for flood mitigation, erosion control and sediment retention and its biodiversity. However, Dominati et al. (2010, p.1861) define that multiple indicators are necessary to assess soil ecosystem services, as they result from multiple

processes or properties. Therefore, “limiting each service to one indicator fails to recognize each soil service is the product of multiple properties and processes.”

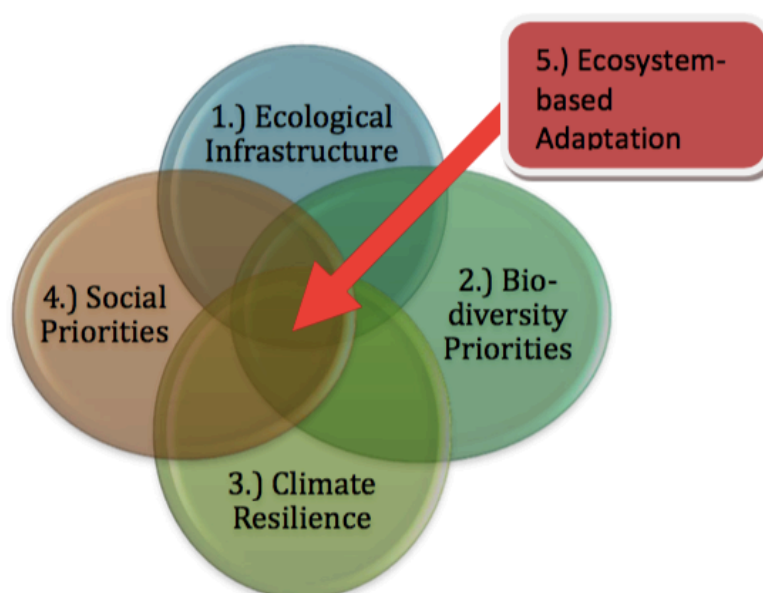


**Figure 4:** Framework for Soil Properties and Provision of Ecosystem Services (Source: adapted from Dominati et al., 2010)

Climatic changes that affect precipitation patterns not only have an impact on the water-related ecosystem services but also the soil-related ones. These impacts can also reflect in the economic activity based on these ecosystem services. Wang et al. (2016) cite from Meze-Hausken (2004) and Oladipo (1985) that agricultural droughts usually have climate origin and they are usually associated with crop reduction or even failure due to changes in soil moisture levels. Dobbie, Bruneau and Towers (2011) state that as temperature and rainfall influence the input of organic matter and also the decomposition process, there is a general concern regarding the loss of organic matter due to climate change in Scotland, which directly affects agricultural activity. Gazol et al. (2018), however, in studying the changes in soil property in drought-induced forest die-off also noticed that though soil water retention capacity decreases in the drought event, soil nutrient availability does not change. Soil microbial community is what changes, which leads to long-term nutrient imbalance. It is clear that water shortage in the event of drought not only affects the level of water availability for plant growth, but more importantly the micro-environment of soils.

## 2.4 Ecosystem-based Adaptation (EbA) Measures

The IUCN in its website<sup>6</sup>, quotes from the Convention on Biological Diversity (CBD) that “Ecosystem-based adaptation (EbA) uses biodiversity and ecosystem services in an overall adaptation strategy. It includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change.” Ojea (2015, p. 41) defines EbA as “practices that promote socio-ecological resilience by fostering ecosystem services, through ecosystem management that enable people to adapt to the impacts of climate change and reduce their vulnerability.” Olivier et al. (2012) argue that though classical development and traditional conservation projects can also promote socio-economic benefits and climate change adaptation, EbA focus on the specific needs for adaptation and socio-economic benefits from the beginning of the implementation plan.



**Figure 5:** The Integration Framework and linkage to Ecosystem-Based Adaptation (Source: Bourne et al., 2015)

In agricultural systems, Vignola et al. (2015) define EbA as practices that use or take advantage of ecosystem services or biodiversity to support the adaptation to climate change and help improve their livelihoods.

Stivari et al. (2014) describe a number of agricultural practices that aim at preserving soil and its features. However, these practices could also benefit the biodiversity and improve resilience of the soil system to droughts. These practices are described in table 1 and they are beneficial for the following ecosystem services: physical support, food and fiber supply,

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<sup>6</sup> Available at: <https://www.iucn.org/theme/ecosystem-management/our-work/ecosystem-based-approaches-climate-change-adaptation>. (Accessed 30 August 2018).

biodiversity habitat (in the provisioning category); nutrient cycling and soil formation, erosion control, control of pests and pathogens, climate and GHG regulation, water supply and regulation (all in the regulating category) (Bayeve, Bayeve and Gowdy, 2016).

**Table 1:** Agricultural Practices that Support the Conservation of Soil for Avoiding Erosion (Source: adapted from Stivari et al., 2014)

Practice	Importance
Soil Sampling	Helps identify areas that need better nutrient adjustment
Liming	Supports the better uptake of organic nutrients. Also helps in the physical structure of soils
Fertilizing	Helps to maximize the crop production
Organic Fertilizing	Fertilizers of volume and low in nutrients, usually of animal origin
Green fertilizer	Plant species for the nitrogen fixation
Crop rotation	Alternate different crops in the same area, so that plagues and the level of nutrients can be better maintained
Weed removal	Done in a way that either the remaining of the weeds are left in the soil or only the superficial part is cut off
Mulching	Dead vegetal covering that protects the soil against water rain impact and washing. It is eventually incorporated to the organic covering layer
Direct seedling	Seedling without soil preparation that disturbs the soil layers

Other practices that could be favorable both to farmers with livestock and to the soils are the sugar cane and grass production for foraging. Macedo, Capeche and Melo (2009) explain that the practice of producing plant species with fast growth rate of both the root system and aerial parts is beneficial to the soil. By adopting such practice, it protects the soils from rainwater splashing or water run off that causes erosion. The authors cite as

example of plants for such practice the sugar cane and forage grass, which are also key crops for the production of forage for cattle.

The use of sugar cane as fodder for beef livestock is quite a popular and traditional practice in Brazil. Pereira (2012) argues that already in the 1950s, 75% of the milk producers in the State of São Paulo fed their cows with sugar cane. It is a perennial crop that can be harvested up to four times if well managed. Livestock feeds well on it and it has relative low production cost (CEPEA- ESALQ, 2012). For the soils, the production of sugar cane for fodder is positive as it protects the soil and the harvest is done manually. Important is, that the cane has to be harvested by chopping it at soil level to ensure that the plant produces further harvest. Also, the upper leaves are usually chopped off and left on the ground, ensuring soil protection against plagues and diseases and maintaining soil moisture (Townsend, 2000).

The production of grass for forage (mostly of the genus *Brachiaria*) has significant importance in ensuring the cattle raising activities in the Brazilian Center-west region, where soils are acid and of low fertility (Correia and Santos, 2003). Grass ensures the supply of dry matter and proteins for the cattle (Oliveira, n.d.).

The key between agricultural practices that are beneficial to the environment, to the producer and classification as practices to adapt to climate change has been defined by Vignola et al. (2015). The authors define three dimensions in which agricultural practices need to fulfill at least one so that they can be classified as Ecosystem- based Adaptation practices:

- *Dimension 1 (ecosystem-based)*: which takes into consideration the sustainability and conservation of the biodiversity and the normal ecological functions such as carbon and nutrient cycling;
- *Dimension 2 (adaptation benefits)*: considers the benefits of adaptation as it helps reducing the impacts of weather events and high temperatures; helps reducing pests, diseases and improves productivity.
- *Dimension 3 (livelihood security)*: Ensures food security and livelihood support; respects traditional practices and it is economically affordable to farmers.

Mfitumukiza et al. (2017) argue that it is important for agro-pastoralists to understand the importance of EbA in building social and ecological resilience to climate change. After analyzing the strategies adopted in a district in Central Uganda, the authors conclude that EbA measures to drought offer opportunities for the improvement of social resilience to climate change. However, Harvey et al. (2017), in studying small coffee producers in Central America, concluded that the adoption of EbA practices were due to other factors rather than adaptation to climate change. For example, the use of shade in coffee systems promoted diversification and alternative income. In analyzing the EbA opportunities in Brazil, Scarano (2017) states that Brazil's NDC (Nationally Determined Contributions) to the UNFCCC is much based on the sustainable land use premises. The author argues that considering the existent legislation on vegetation protection, Brazil can potentially have the largest EbA program at the national level.

Harvey et al. (2017) argue that if on the one hand EbA practices are defended as ideal strategies for smallholder farmers to adapt to climate change, on the other hand more systematic and detailed information is needed on what practices are adopted, how they vary from region to region and what factors influence the adoption of these practices.

## 2.5 Coping Strategies to Drought

Coping capacity refers to the “ability of people, organizations, and systems, using available skills, resources, and opportunities, to address, manage, and overcome adverse conditions” (Lavell et al., 2012, p.33). Van der Geest and Schindler (2017) state that academically, a coping strategy is the action taken to ensure survival or that routine gets back to usual right after an adverse event. It differs from adaptive capacity, which can be defined as “the combination of strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities.” (Lavell et al., 2012, p.36). The CARE’s Climate Vulnerability and Capacity Analysis Handbook presents the main differences between adaptation and coping capacities, as it can be seen in the table 2.

**Table 2:** Difference between Coping and Adaptation (Source: Adapted from CARE CVCA, 2012)


<b>Coping</b>	<b>Adaptation</b>
Short term and immediate	Aims longer term livelihoods security
Oriented towards survival	Continuous process
Not continuous	Results are sustained as resources are used efficiently and sustainably
Motivated by crisis, reactive	Involves planning
Prompted by a lack of alternatives	Focused on finding alternatives

As stated by Wang et al. (2016), one of the ways of coping with drought is through water resource projects that ensure the water supply under critic climatic and hydrological conditions. In analyzing the coping and adaptive strategies adopted by pastoralists of Northern Kenya, Opiyo et al. (2015) found out that the sale of livestock and livestock products, slaughter of old livestock, searching for alternative employment in towns and reducing food consumption in the household were the main coping measures adopted. The main adaptive measure adopted was the diversification of livelihood to complement pastoralism, including activities such as honey production and wild fruit picking. Also, the diversification of livestock, alternative employment and improvement of technical skills were pointed out as adaptive measures to the increasing frequency of drought in the region. (Opiyo et al., 2015, pp. 303, 304).

### 2.5.1 Finance

Chantararat (2015) argues that as climate risk can expose to losses, the lack of mechanisms to finance climate risk can also jeopardize the long-term economic development of a certain area. In the Greater Mekong Subregion, rural communities adopt various strategies to enhance resilience to climate-related disasters, though some of these strategies do not fully protect the rural households or even contribute to long term vulnerability to natural hazards (Manuamorn, Chantararat and McLeod, 2017). Moreover, the same publication states that “effective climate risk management in rural communities requires climate risk finance” (p.2). Understanding the impacts due to climatic events in rural communities and financial consequences at the individual level is fundamental to determine what gaps need to be filled and what approaches in risk finance can be adopted at the institutional level. Table 3 represents the risk layering framework and correlation to financing options accordingly.

**Table 3:** The Risk Layering Framework (Source: Adapted from Manuamorn et al., 2017)

	Low impact		High impact
			
	<b>Risk retention</b>	<b>Risk sharing</b>	<b>Risk transfer</b>
Households (individual level)	Savings	Social insurance	Microinsurance
Communities	Community funds	Regional pool of disaster funds	Insurance
Governments	Disaster funds, contingency credits	National pool of disaster funds	Insurance, catastrophe bonds

According to Chantararat (2015), risk retention is understood as financial mechanisms which deal with low impact events that are usually the result of high frequency events. Risk sharing covers mechanisms that deal with medium impact and medium frequency events, while risk transfer includes mechanisms that deal with low frequency but high impact events that result in high economic losses.

Chantararat (2015) claims that although households in Cambodia, Lao PDR and Vietnam commonly use the strategies to cope with climate events, they are often ineffective, and they could jeopardize the further individual economic development. Weingärtner, Simonet and Caravani (2017) argue that risk transfer mechanisms, such as insurance, are important particularly in avoiding losses from high impact events as a disaster risk management tool. Insurance, as argued by the authors, could also support the economic development by avoiding fragmented economic activities and impacts in the health of the population. However, they admit that in developing countries there is a great financial gap and a low developed insurance market. Cooper (2012) argues that, though in the Copenhagen Accord of December 2009 rich countries were pledged to provide US\$1000 billion a year by 2020 to support the mitigation of greenhouse gas emissions, the funding would be of better use if used for adaptation to climate change instead.

Economic losses due to natural disasters in developing countries are rising, which potentially increases the need of insurance coverage and other risk management strategies (Weingärtner, Simonet and Caravani, 2017). Though risk transfer mechanisms such as insurance are mentioned as positive for the sustainable development of agricultural activities, the same authors also admit that there is a lack of evidence to assess the long term sustainable positive effects in the context of climate change.

### 2.5.2 Migration

Adapting to local climatic changes is a matter of survival. Warner (2010) argues that migration and displacement are possible adaptive responses to changes in the environment caused by climatic changes. For rural households, food security is a variable directly related to changes and adaptive measures. The “Where the Rain Falls” research project, in eight case studies, evaluated in what cases rural households adopted migration as a strategy to ensure food security in case of changes in precipitation patterns due to climatic changes (Warner and Afif, 2014). Another research objective of the project was to analyze how policies can increase the chance of migration remaining a choice for increasing resilience. Therefore, migration is either a coping strategy or adaptation strategy depending of the context and impact of the event. Warner (2010) argues that one difficulty in defining the range of migration due to environmental changes is the fact that there are institutional and governance implications as the type of migration defines which institution is responsible for dealing with it. Rapid and slow-onset situations define the type of migration, whether they are permanent or temporary or internal or international displacement. The same author also argues that migration due to rapid-onset events is easier to identify than in the case of slow-onset events, as the latter provide the opportunity of intervention in building up resilience before the need of displacement.

In analyzing the effects of climatic variability on human displacement in South America, Thiede, Gray and Mueller (2016) concluded that changes in temperature trigger more migration than changes in rainfall pattern. They also found out that climatic variability influences regional displacement, particularly inducing displacement to urban areas, regardless whether they are rural-urban or urban-urban types of migration. However, the authors admit that one research gap is the difference among intra-regional migration due to climatic changes, as they vary from country to country.

Hugo (2011) defends the fact that environmental change and demographic change can be independent factors that cause migration. Migration is not necessarily result of increase in population but in the extrapolation of the carrying capacity of the environment. Furthermore, the author states that the areas with most rapid population growth are also the ones more vulnerable to effects of climate change and therefore more vulnerable to extrapolations in its carrying capacity. Thus, the need of increasing the efforts in planning settlements and associating populations more vulnerable to climate change is imperative.



## 2.6 Limits to Adaptation and Adaptive Capacity to Climate Change

The importance of adaptation to climate change is unquestionable. However, Dow, Berkhout and Preston (2013) argue that as climate change increases pressure in the natural and human systems, the likelihood of exceeding the limits to adaptation of these systems grow substantially. Though all human and ecological systems are capable of adapting to new limits, there will be inevitable losses, such as those caused by migration, like loss of cultural systems and economic impacts in the case of human systems.

Klein et al. (2014) define the difference between adaptation barrier, constraint, obstacle, and limit. The authors argue that a constraint is a “factor or process that makes adaptation planning and implementation more difficult” (Klein et al. 2014, p.906) and in this case constraint is synonymous with barrier or obstacle. Adaptation limit, as argued by the authors, is more restrictive, as it means that “adaptation is not possible over a certain time horizon” (Klein et al. 2014, p.906). Dow, Berkhout and Preston (2013, p.387) define the adaptation limit as “the point at which an actor’s objectives cannot be secured from intolerable risks through adaptive actions.”

Nelson et al. (2007) cited in Dow, Berkhout and Preston (2013) state that concepts such a tipping point and key vulnerability imply that society may not be able to overcome the changes in the environment caused due to climate change.

Dow et al. (2013, p.306) suggest the definition of adaptation limit as the point which “an actor can no longer secure valued objectives from intolerable risk through adaptive action.” The authors defend that the definition of adaptation limits is important so that plans to avoid hardships can be made beforehand. And as adaptation processes are built upon attempts to keep risks low, the authors argue that the perception of climate-related risks change depending of the individual willingness to reduce risks.

As perception to climate change is what motivates farmers to adapt, Alves et al. (2017) analyzed the perception of farmers in the region of Zona da Mata Mineira, Minas Gerais, Brazil. The majority perceives the changes in climate patterns, but a minority has introduced adaptive measures for such. Pires et al. (2014), in evaluating the perception of climate change among farmers in the state of Minas Gerais found out that most farmers perceive climate change and as a result, some have introduced changes in the farming activities, such as changes in the sowing period and introduction of irrigation systems. In the study, the authors identified several problems in adopting alternative measures to climate change. These difficulties included lack of financial resources and technical support.

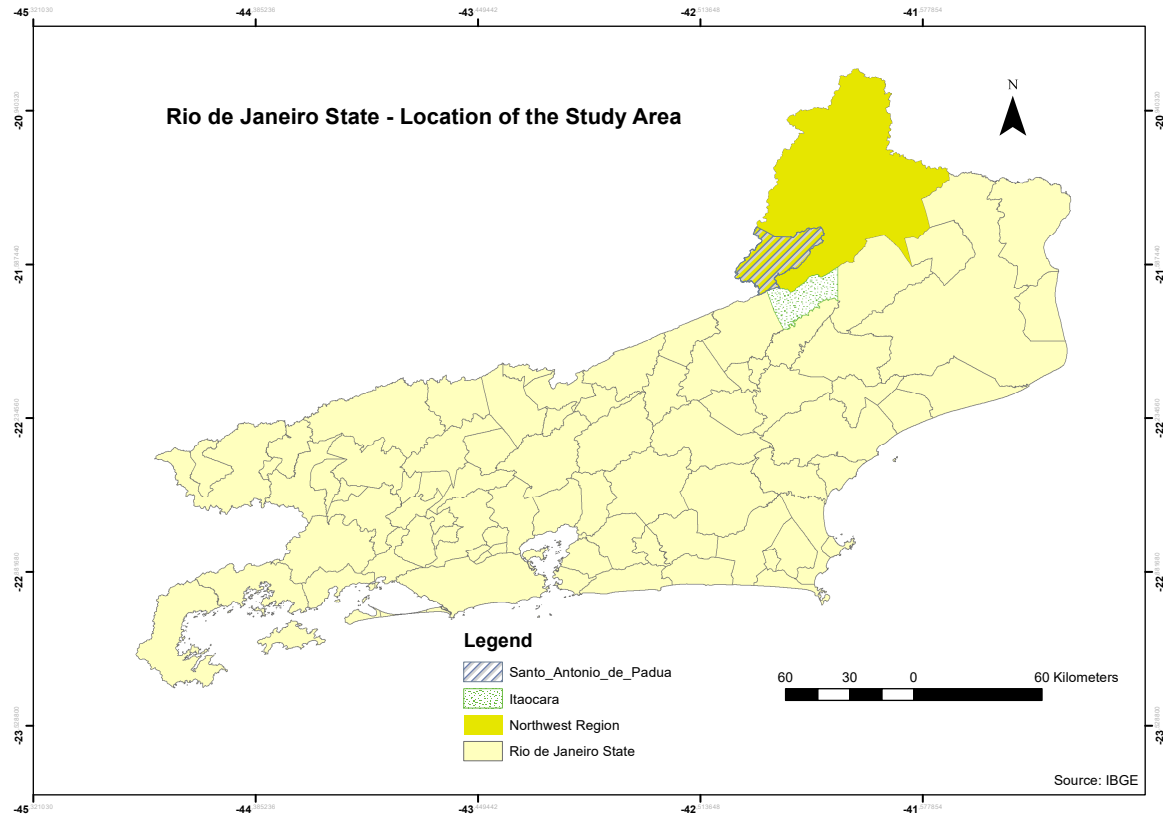
In measuring adaptive capacity of farmers to climate change in an agricultural community in the Philippines, Defiesta and Rapera (2014) found out that farmers adapt to climate change in order to ensure survival and that the level of adaptive capacity is directly correlated to their availability of resources. The poorer the farmer, the simpler were the adopted measures and thus the lower their resilience. Abdul-Razak and Kruse (2017), in studying adaptive capacity to climate change in the Northern region of Ghana, found out that though most farmers have a low adaptive capacity, there was a significant difference between the capacity of the male and of the female smallholder farmers. Females had lower

adaptive capacity, correlated to the fact that they had less access to schooling. Perez et al. (2015) in studying adaptation to climate change in four countries in East Africa and five in Central Africa, noticed that the question of resilience and adaptive capacity is closely related not only to access to education (which women have less) but also to the acceptance of women in the working communities.

Therefore, adaptive capacity varies from community to community as well as the difficulties in implementing the measures to ensure better resilience to climate change.

### 3. Study Area

The municipalities of Itaocara and Santo Antônio de Pádua are two of the thirteen municipalities that comprise the Northwestern region of Rio de Janeiro State (State Law 1227/1987). Figure 6 shows the location of the Northwest region within the Rio de Janeiro.



**Figure 6:** Northwest Region of Rio de Janeiro State and Study Area (Source: IBGE, own design)

Both municipalities are located within the Paraíba do Sul River basin, the Paraíba do Sul river crossing through Itaocara and the Pomba river through Santo Antônio de Pádua. The original vegetation of the area is described as semidecidual rainforest as part of the Atlantic Forest (Mata Atlântica). However, most of the original vegetation has been devastated since colonial times, for the purpose of wood extraction and later for coffee plantations. Coffee and sugarcane production were the main economic activities in the region between the 19<sup>th</sup> and beginning of the 20<sup>th</sup> century. Following the coffee and sugarcane production phase, cattle raising became the main economic activity in the region. The decline in coffee production led to the economic and population fall. The farming structure, once based on large productive properties, shaped up into small properties adopting poor land use practices. Rice production has also been important in the region, but due to lack of economic incentives, the production has been in gradual decrease to the point of nearly disappearance. It has been replaced by the production of variable vegetables, such as tomatoes and cucumbers (SEA, 2015).

According to Lumbreras et al. (2004), both municipalities have the same pedological features, in which areas are highly dissected and predominant soils are naturally fertile with medium water capacity available. Moreover, the authors argue that the area has a particular intense dry season, in which in 4-6 months of the year monthly precipitations are as low as 60mm. Therefore, due to this climatic feature and the low water retention capacity of soils, the authors argue why the area has restricted agricultural activities and broadened cattle raising activities for milk and beef production. Moreover, the intense dry period followed by intense raining days, they add, have contributed to the increase of eroded areas, as the precipitations affect the soils with little or no green covering.

Itaocara, particularly, has a stronger agricultural economy than Santo Antonio de Pádua. This is evidenced through the crop products and quantity of milk produced. Properties are mainly of smallholder farmers. According to the Brazilian National Law no. 11326 issued in July 2006, a familiar farmer, or a smallholder farmer is one that the property is not larger than four fiscal modules and under the family's management. The size of the modules is established in hectares and they vary from municipality to municipality.

According to INCRA, in its National Rural Register, the fiscal module in Itaocara is of 22ha and in Santo Antonio de Pádua 35ha. Therefore, in Itaocara properties up to 88ha and in Santo Antonio de Pádua 140ha are considered small properties. Schneider (2016) states that the average family farm in Brazil is 18.35ha. In this study the average 20ha was the reference for the size classification of smallholder farms in the study region.

### 3.1 Itaocara

According to the Brazilian Institute of Geography and Statistics (IBGE), the municipality of Itaocara has approximately 431.30 km<sup>2</sup> and estimated population of 22,600 inhabitants (IBGE, 2018). The location of the municipality within the State can be observed in figure 6.

Its GDP ranks in 20th place out of 92 municipalities in the whole Rio de Janeiro State. The GINI coefficient for the municipality is 0.45. The main harvested crops in 2017 are shown in table 4:

**Table 4:** Main Crops Harvested in 2017 (Source: EMATER- Rio, 2018)

Crop	Harvested quantity (in tons)
Okra	2,392
Mango	1,700
Garden egg	1,547
Eggplant	973
Green bell pepper	874
Tomato	795

Agricultural activities are the second most important economic source in the municipality, followed by the tertiary sector and industry. These activities represented circa 5.6% of the total economic activity in the municipality. According to the EMATER –Rio (2018), in 2017 the total production was 9,404 tons in 574 properties.



**Figure 7 and 8:** Typical Tomato and Okra Fields in Itaocara

Vegetables and milk are the main agricultural products in the municipality. In Itaocara there is a milk cooperative which receives most of the milk produced in the municipality and also from some producers from neighboring municipalities. The total amount of milk received and processed by the cooperative in 2017 was of 26,403,369 litres.

The FAO defines small-scale farmers as those who manage areas from less than one hectare to 10 hectares (Rapsomanikis, 2015). In Itaocara, most farmers fall into the category of small-scale family farmers, with properties under 88ha. According to the local EMATER office, there are approximately 1,600 farming properties in the municipality, from which approximately 52% are not larger than 10 hectares.

Moreover, most producers tend to have a mixed crop and additionally a few animals for milk production. Few of the overall producers are exclusively milk producers or crop growers.

### 3.2 Santo Antonio de Pádua

The municipality has the total area of 603,357 km<sup>2</sup> and estimated population of 40.590 inhabitants (IBGE, 2018).

Its GDP ranks in 40<sup>th</sup> place out of 92 municipalities in the state and the GINI coefficient for the municipality is 0,48. The main harvested crops in 2017 are shown in table 5:

**Table 5:** Main Crops Harvested in 2017 (Source: EMATER- Rio, 2018)

Crop	Harvested quantity (in tons)
Tomato	2,034
Green bell pepper	240
Coconut	180
Eggplant	144
Banana	180

Agricultural activities are the third source of income in the municipality, following the tertiary sector and industry. In 2017, the total production in the municipality was 3,154 tons in 203 properties under 135ha. Much of the milk produced in Santo Antônio de Pádua is either sold informally or sent directly to dairy companies. There is no organized local milk production cooperative for the processing of milk as there is one in Itaocara. According to the local EMATER office, in 2017, circa 13,130,331 litres of milk were produced in the municipality.



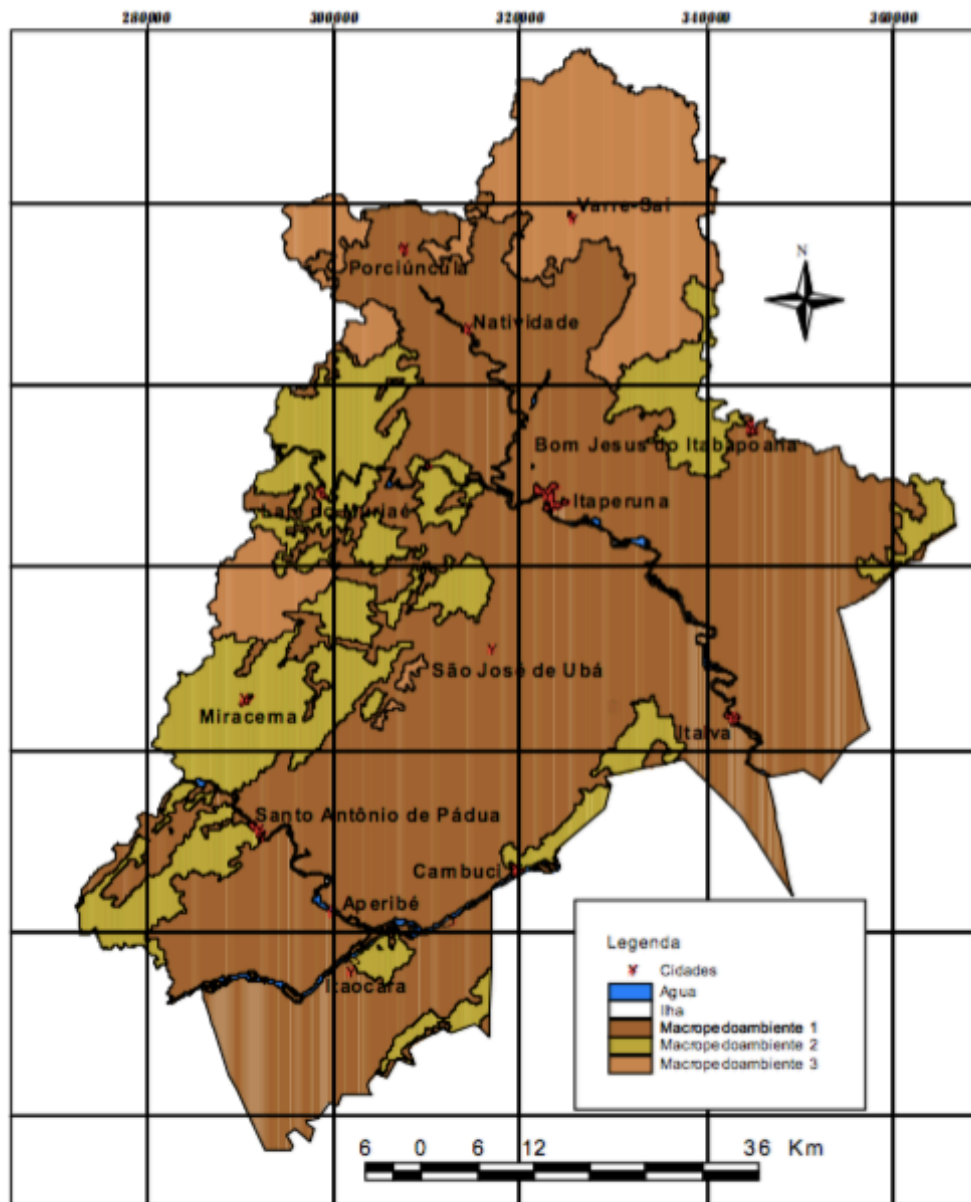
**Figure 9 and 10:** Typical Properties in Santo Antonio de Padua, with Grass Forage Field and Water Pond for the Cattle

Most properties in this municipality have cattle raised for beef. Minority of properties have commercial crops or milk production at commercial scale. The local EMATER office has in its roster of producers approximately 1,300 properties.

### 3.3 Soils and Geomorphology in the Northwest Region of RJ

With respect to the pedological features, Lumbreras et al. (2004) classify the Northwest region of Rio de Janeiro State into three distinct categories (Macro-soil environment 1, 2 and 3). According to this categorization, Itaocara and Santo Antonio de Pádua are located

in the Macro- soil environment 1 (figure 11). Most of the Northwest region presents this type of soil environment.



**Figure 11:** Macro-pedological Environments in the Northwest of Rio de Janeiro State (Source: Lumbreras et al., 2004)

According to the authors, the areas are much degraded, and the soils are predominantly of high natural fertility and medium to low water holding capacity. The soil is characteristic of Red Argisol and Red-Yellow Argisol types. (Lumbreras et al., 2004)

Anjos and Pereira (2013) define Argisols as soils with significant amounts of clay in the B-Horizon when in comparison to the A-Horizon. The natural fertility varies, and in some cases, they may contain high levels (equal or more than 50%) of Aluminum. The relief of the area is undulated to strongly undulated, which influences the soil features. It is a type



of soil broadly found in the whole state of Rio de Janeiro. Regardless of the type of use, the authors note that this kind of soil is highly susceptible to erosive processes.



**Figure 12:** Typical Undulated Landscape of Itaocara

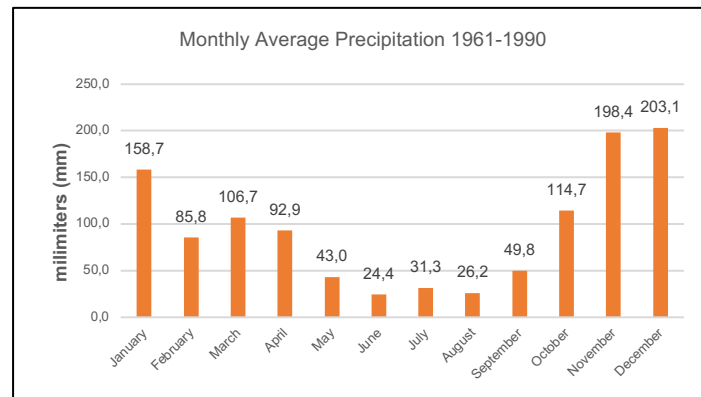
Lumbreras et al. (2004) argue that due to the climatic conditions of the region with defined wet and dry seasons, the low water retention capacity and the undulated relief (figure 12), the land use is restricted mostly to cattle raising for beef and dairy production, with small areas with crop growing activity.

### 3.4 Climate

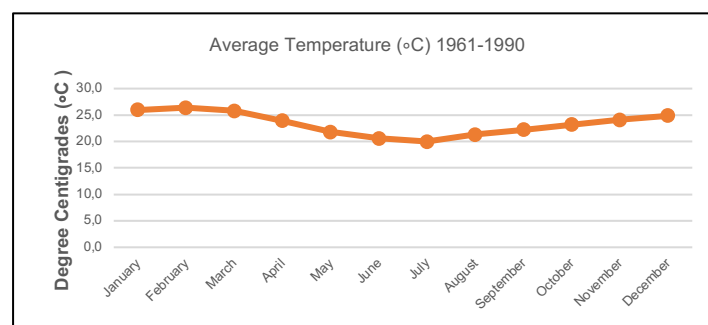
Brandão et al. (2015) describe the climate of Santo Antonio de Pádua as tropical with dry season in the winter (Aw) according to the Köppen and Geiger classification. The authors also observed that in the dry winter months from June to August, precipitations do not go beyond 50mm per month. This description is similar to the monthly average precipitations in the region as shown in figure 15. Being Itaocara in the same region, the precipitation pattern can also be considered similar. According to the bioclimatic mapping performed by Cronemberger et al. (2011), both municipalities are located in a tropical subhumid climate area.

When analyzing the precipitations in the region between 2012 and 2017, there is a significant change in the season and difference in the quantity of precipitation expected and recorded.





**Figure 13:** Monthly Average Precipitation (in mm) in Itaperuna, RJ in the Period 1961- 1990 (source: INPE, 2018)



**Figure 14:** Average Temperature (in °C) Measured in Itaperuna, RJ between 1961- 1990 (source: INMET, 2018)

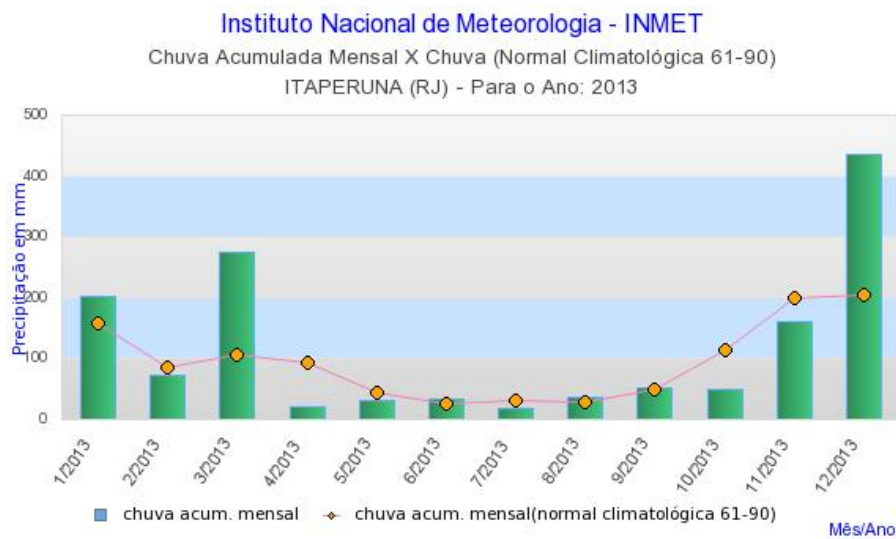
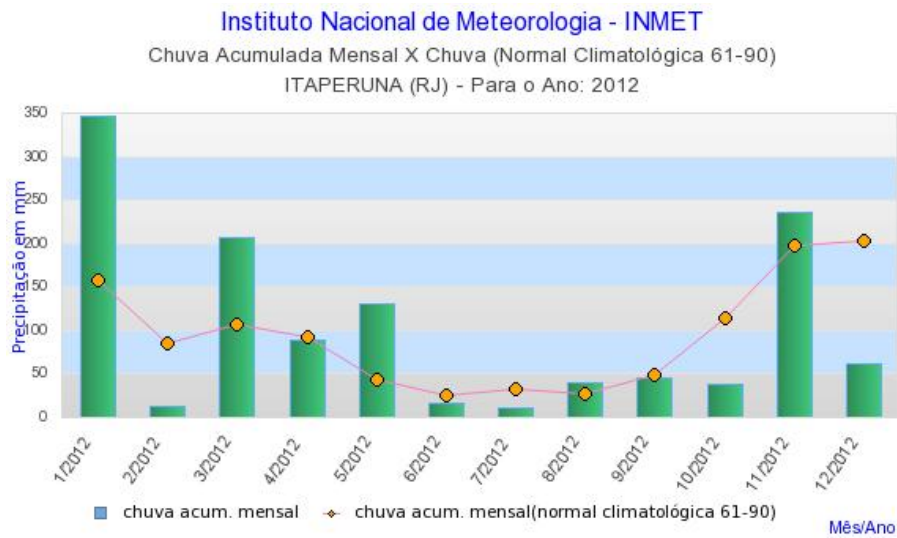
### 3.4.1 Climate Change in the Municipalities

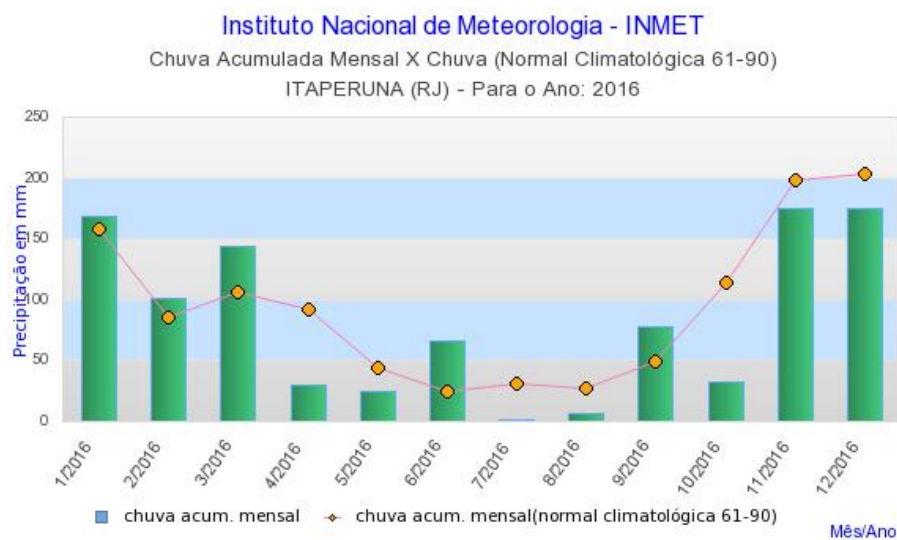
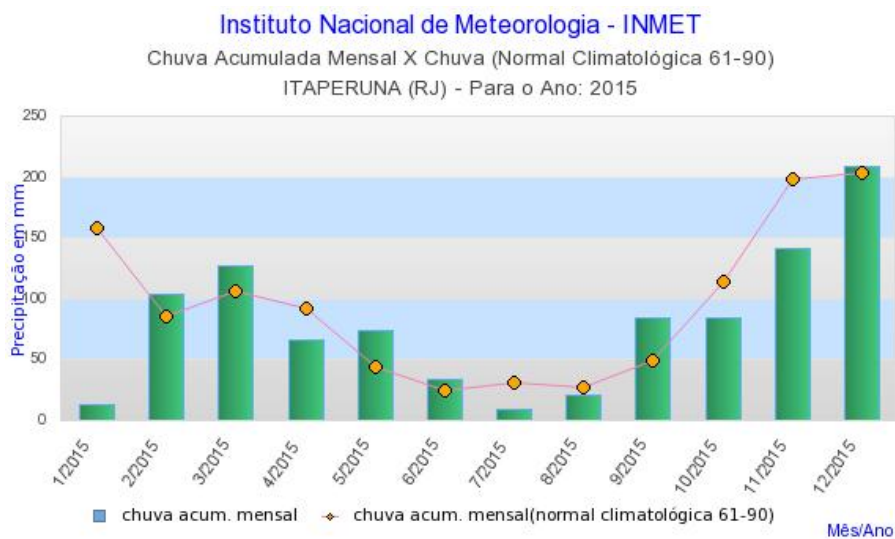
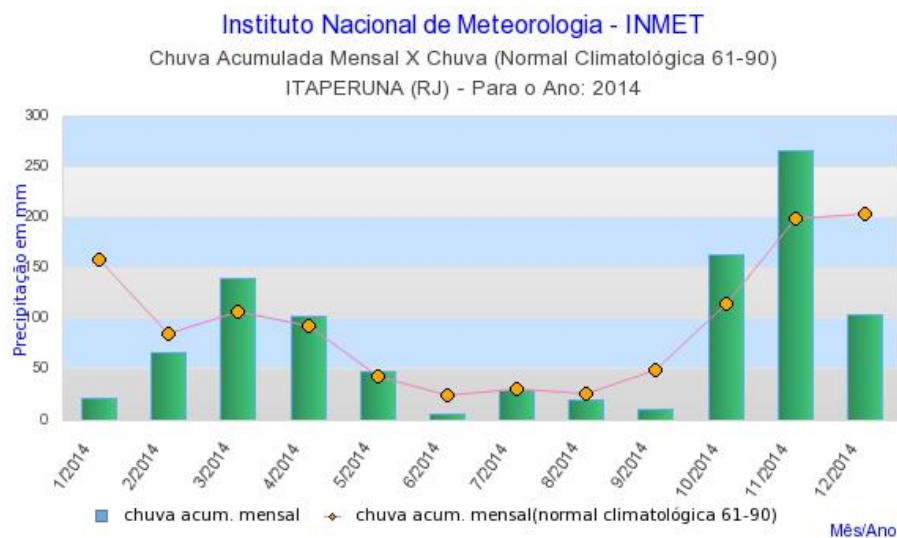
In analyzing the historical climate variations in the Southeast Brazil, Nehren et al. (2019) evidenced that landslides, mudslides and flood events, such as the 2011 event in the Serrana region of Rio de Janeiro, have historically occurred in the region. These events always had significant impacts in urbanized and land-degraded areas. The authors add, however, that other meteorological events such as droughts, are not historically registered. Nevertheless, they point out that there is the indication that the regional climate is becoming drier, though not enough meteorological data is available to evidence it.

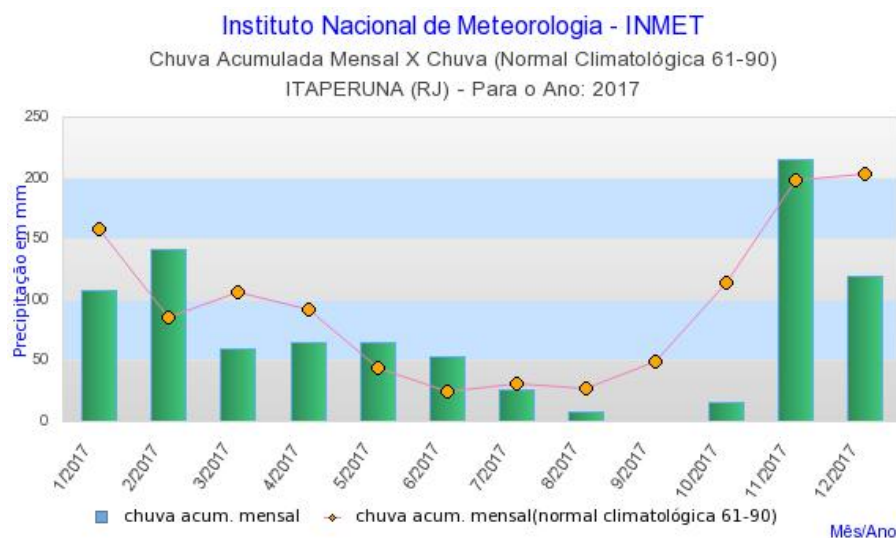
Though it is argued that climatic events such as the droughts that affected southeast Brazil between 2014-2017 might not be consequence of global climate change, Nehren et al. (2019, p.322) agree that changes in climate, related to the increasing GHG emissions, will affect the entire country, and that “less precipitations and higher temperatures could therefore further dry up the semiarid and subhumid regions of RJ.” Both municipalities, Itaocara and Santo Antonio de Pádua are in these regions.

The official recorded precipitations presented by the INMET were based on the information collected from a meteorological station in the municipality of Itaperuna, in the same region

(approximately 85 km from Itaocara and 70 km from Santo Antonio de Pádua). The alterations in the precipitation patterns can be observed in the figures 15-20.







**Figure 15, 16, 17, 18, 19 and 20:** Monthly Accumulated Precipitation X Monthly Climatologic Accumulated Precipitation Measured Between 2012 and 2017 in Itaperuna, RJ (source: INMET)

When comparing these precipitation data collected in Itaperuna and the precipitation data collected in the municipalities of Itaocara and Santo Antonio the Pádua, the same pattern of alterations in precipitations can be observed in the Annexes 9.2 and 9.3.

### 3.5 Drought Prevention

Drought is considered a hydro-meteorological hazard, which, according to the UNISDR, calls for disaster risk reduction measures (UNISDR, 2009). However, the State Plan for Civil Defense and Protection, launched in 2013, does not consider drought a threat. For this reason, drought risk reduction measures are not part of the Rio de Janeiro State agenda.

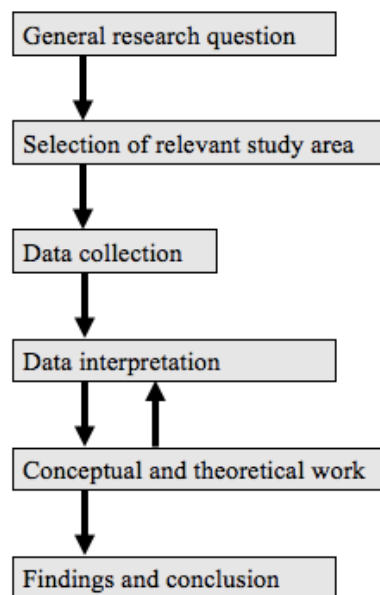
In 2017, during the drought event, the municipalities of Itaocara and Santo Antonio de Pádua, respectively, issued their drought emergency decrees.

The Municipal Decree 1556, issued in 02 October 2017 in Itaocara, declared the state of emergency due to the extended drought. In Santo Antonio de Pádua similar decree was issued in 29 September 2017.

In both municipalities, the text of the decrees only ensured the safety of individuals in case of extreme danger and the possibility of public acquisitions without any previous bidding. The decrees do not mention specific actions to minimize impacts or to support coping measures adopted by the smallholder farmers.

## 4. Methodology

The nature of the assessment was predominantly qualitative. As defined by Bryman (2016), a qualitative research usually highlights words, not the quantity of data to be analyzed. Qualitative research explores the relationship between theory and research. Foster (1995), cited by Bryman (2016) defines the main steps in qualitative research as presented in the following figure 21:



**Figure 21:** Steps in Qualitative Research (modified from Bryman, 2016)

The step of data interpretation is directly related to the conceptual and theoretical framework defined for the research project. These two steps are the basis for the writing of findings and the conclusion for the project, which has to be significant and convincing for the audience.

The author cites some contrasts between the qualitative and quantitative research that may count both as advantages and disadvantages for each of the methods:

*Structured vs. Unstructured:* When the research is structured, as in the quantitative research, concepts and issues are directly analyzed, whereas the unstructured research allows the interviewee's meanings to be enhanced in the data collection process;

*Point of view of researcher vs. Point of view of participant:* In quantitative research the researcher is in control of the information obtained and in qualitative research the researcher is an observer;

*Number vs. Words:* Quantitative research emphasizes the measurements and qualitative research the meanings;

For this project, the choice of a qualitative method seemed more adequate as the objective of the project was to obtain data based on the experience of smallholder farmers and compare to the existing theories and proposals of adaptive measures to climate change.

Sampling for the research was according to the following approaches, defined by Patton (1990) and Palys (2008) in Bryman (2016, p.409):

- Criterion sampling: form of sampling individuals “that meet a particular criterion”;
- Opportunistic sampling: in which the opportunity to collect data was used to get in touch with individuals with whom the contact would be not expected;
- Snowball sampling: the interviewer initially samples an individual and this individual proposes other participants who have the experience that may be relevant for the research.

In regard to the size of sampling, Bryman (2016, p.416) admits that defining a number of samples can be difficult. The author cites from Warren (2002) that a qualitative research should have a minimum of 20 to 30 interviews. However, the author cites from Gerson and Horowitz (2002) that “fewer than 60 interviews cannot support convincing conclusions.” Therefore, Bryman (2016, p.417) agrees that the size of the sample has to be “able to support convincing conclusions is likely to vary from situation to situation.”

Due to the lack of previous studies that resulted in similar results, the questionnaires for the assessments were elaborated with the purpose of gathering the needed information for the objectives of this study. The elaboration of questionnaires used for this study was based on the research methodologies from CARE International (2009), Warner et al. (2012) and Van der Geest and Schindler (2017). The assessment methodology comprised the following steps:

- Participatory focus group interviews
- Semi-structured individual interviews with producers
- Open question interview with experts at the local, regional and national levels.

As defined by Merton et al. (1956) in Bryman (2016), the group interviews and individual ones can be characterized as focused interviews, as in the interviews the questions were mostly of open-ended questions. Gehringer and Weins (2009) define that open-ended questions, as opposed to close- ended questions, are better used if there are different or infinite possible answers.

For the expert interviews, according to the definition of Bryman (2016), the interviews were qualitative interviews, as they included semi-structured and unstructured features. The author defines semi-structured interviews as interviews with questions as general guides, which allows the sequence of questions to be varied. Questions generally allow the interviewer to ask further questions so that the response can be more adequate and expected as reply. Now unstructured interviews are defined as interviews with only a list of topics or issues, in which they are informally asked and can be asked randomly.

The assessment was conducted in the months of May and June 2018. The month of May was dedicated to the assessment in Itaocara and June to Santo Antonio de Pádua. The expert interviews were conducted from May to July 2018.

In Itaocara the group meetings were organized by the local EMATER office with the objective of gathering producers for other specific objectives, so opportunity was used to perform the group interviews. In Santo Antonio de Pádua one of the meetings was organized by the local prefecture for the delivery of relevant information and the opportunity was used for this project. One group gathering in this municipality was organized with the exclusive purpose of performing the group assessment.

Producers for the individual interviews were also randomly selected, following a mix of criterion sampling and snowball sampling.

As this study aimed to analyze the adaptation strategies in the Northwest Rio de Janeiro State and how they are dealt at the state and national levels, interviews with experts at the respective levels were included. At the local level, professionals with involvement in the agricultural activities at the studied municipalities were selected. Similarly, the experts at the regional level were selected based on the level of involvement in the governance process of climate change adaptation in the State of Rio de Janeiro. At the national level, the experts were selected based on their involvement in the climate change issues at the national level. Some of these interviews were conducted personally and some of them were conducted by telephone due to the availability of the interviewees.

Experts were selected mostly through the snowball method. The local expert in Itaocara was selected based on the recommendations made by some of the interviewed farmers. Similarly, in Santo Antonio de Pádua, where the selected expert was the secretary of agriculture, recommended by the EMATER technicians. The regional experts were contacted through the EMATER technicians, who recommended these experts as the best ones to answer questions related to adaptation to climate change in Rio de Janeiro. The selected national expert was a recommendation from one of the Rio de Janeiro State experts.

#### 4.1 Participatory Focus Group Interviews

The participatory focus group interviews were held with the purpose of gathering information from a community point of view, which could demonstrate a different view of adaptation beyond the measures adopted at the individual level. Bryman (2016, p.409) classifies this sampling approach, based on Patton (1990) and Palys (2008) as criterion sampling. A criterion sample is a form of sampling individuals “that meet a particular criterion.” For the group interviews, all rural producers were invited to attend the meetings, regardless whether they were landowners or tenants or, whether they had mixed production or were exclusively crop growers, milk producers or cattle for beef raisers.

Participants were asked to share their perceptions on changes in the climate leading to drought due to extended dry periods, as well as adaptive measures and needs to improve

resilience to these changes. In Itaocara and in Santo Antonio de Pádua, the group interviews were performed in two distinct areas of the municipality and with a varied number of producers and profiles. The group interviews had an average of ten participants, which complies with the argument of Morgan (1998a) in Bryman (2016, p.506), that the “typical group size is six to ten members.” Following the tendency cited by Bryman (2016), that in focus group sessions the moderator uses a small number of questions for the purpose of guidance, there were eight guidance questions.

## 4.2 Semi-structured Individual Interviews with Producers

For the individual interviews, the producers were randomly chosen, basically using the criterion sampling approach. In some cases, there was the use of the snowball sampling approach when a respondent indicated another farmer for the interview. Some were interviewed in their properties, some were interviewed when they visited the EMATER office in both municipalities, and some after the group interview sessions. Minorities, such as women landowners, were not distinctly chosen and picked for the interview.

For the question regarding the EbA measures adopted by the farmers, the types of EbA measures adopted were considered the measures for good soil management practices adopted by the farmers.

### 4.2.1 Individual Questionnaire

Table 6 presents the questions used in the individual interviews:

**Table 6:** Questions of the Individual Questionnaire

General Questions			
1. Age	2. Schooling		
Less than 20 ( )	Not literated	( )	
20-30 ( )	Basic schooling	( ) completed	( ) incompleted
30-40 ( )	Secondary schooling	( ) completed	( ) incompleted
40-50 ( )	Higher education	( ) completed	( ) incompleted
50-60 ( )			
60-70 ( )			
More than 70 ( )			
3. How many people live in the property? _____			
4. Do they all work in the property? _____			
Climate Change Perception			
5. What have you noticed that has changed in the climate?			



<p>More rain in frequency and quantity ( )  Less rain in frequency and more in quantity ( )  Less frequent rain and less in quantity ( )  Warmer ( )  Colder ( )  Drier ( )  More winds ( )</p> <p>6. How about soils, what has changed?</p>
<p><b>Property and Land Use</b></p>
<p>7. The property is ( ) private ( ) leased  8. Size? _____  9. All productive? ( ) Yes ( ) No  If not, ( ) with protected área (legal reserve)? Size _____  ( ) Degraded (erosion?)  Old degraded ( ) after the droughts ( )</p> <p>10. Does it have a water spring? Riparian forest? _____ Water pond? Dried out? ___ ?  Dried out? Changed the flow? _____</p> <p>11. How many animals are there in the property?  ( ) Cows ( ) Bulls ( ) Chickens ( ) Pigs ( ) Sheep/Goats</p> <p>12. Did you lose animals during the last drought? ( ) yes ( ) no  a. Have you replaced them? ( ) yes ( ) no</p> <p>13. Due to the changes of soil quality during the drought, did you lose productive area?</p> <p>14. Did the production of milk decrease during the drought? ( ) yes ( ) no  a. Has it come back to usual? ( ) yes ( ) no  b. Or has it never come back? ( ) yes ( ) no</p> <p>15. Irrigation system? ( ) yes ( ) no  16. Always had ( ) yes ( ) no or since the droughts? _____  17. Do you use organic fertilizers?  18. Do you think you need more fertilizers after the drought?  Do you rotate crops? Pasture? How do you remove weed?  Burn the rests of weed removal? Do you sample soil for analysis?</p> <p>19. Were there more eroded areas after the drought?</p>
<p><b>Other Income Sources/ Migration</b></p>
<p>20. Since the droughts, do you have another job? ( ) yes ( ) no  21. Do you consider moving permanently to the urban area due to the droughts (either if they become irregular or constant)? ( ) yes ( ) no  22. If there is drought every year, do you consider moving?</p>
<p><b>Finances</b></p>
<p>23. Did you need to borrow money, either in the bank or from friends/family due to the droughts? ( ) yes ( ) no  24. Have you used your own savings? ( ) yes ( ) no  25. Did you need to sell property? (Car, tractor, animals, land) ( ) yes ( ) no</p>

Efficiency of the Adaptive Measures and Coping Capacities	
26. Did you need to borrow money, either in the bank or from friends/family due to the droughts? ( ) yes ( ) no	
27. Have you used your own savings? ( ) yes ( ) no	
28. Did you need to sell property? (Car, tractor, animals, land) ( ) yes ( ) no	



**Figure 22:** Individual interview with Farmer in Itaocara

### 4.3 Open- Question Interview with Experts

In order to gather the different views of the importance of adaptation in response to the extended dry season that resulted in drought in both municipalities, a series of experts at the local, state and national level were selected to deliver their views on the problems in ensuring adaptation and the gaps in governance for enhancing resilience and minimizing losses due to climate change. There was a set of common questions, presented in the table 8, and some specific questions were included depending of the expertise of each professional that was interviewed. Though the objective was to interview each expert in person, due to their availability some of them were interviewed by phone. Table 7 presents a brief presentation of each interviewed expert.

**Table 7:** Profile of the Interviewed Experts

<b>Name</b>	<b>Position</b>	<b>Organization</b>	<b>Area of expertise</b>	<b>Sector/ Stakeholder Category</b>
Mr. José Matias Rocha	Head of the EMATER office in Itaocara	EMATER Rio	Agricultural practices in Itaocara	State government organization (acting locally)
Mr. Waldir Neto	Santo Antonio de Pádua Municipal Agriculture Secretary	Santo Antonio de Pádua Municipal Secretary of Agriculture	Agricultural practices and local policies in Santo Antonio de Pádua	Local government organization
Ms. Helga Hissa	Sustainable Rural Development Program – Rio Rural Program Technical Coordinator	Secretary of Agriculture, Livestock, Food Supply, and Fisheries of the State of Rio de Janeiro	Sustainable agricultural practices implemented in the state through the Rio Rural Program	State government organization
Ms. Olga Martins Wehb	Climate Change Superintendent	Rio de Janeiro Environmental Secretary	Mitigation and Adaptation to climate change measures and policies in the Rio de Janeiro State.	State government organization
Mr. Nelson Teixeira	Superintendent of Sustainable Development	Secretary of Agriculture, Livestock, Food Supply, and Fisheries of the State of Rio de Janeiro	Agricultural practices and policies related to the Rio Rural Program and agricultural sustainable development in the state.	State government organization
Dr. Carlos Nobre	Climate Change Researcher, IPCC Research Contributor	Brazilian National Council for Scientific and Technological Development (CNPq)	Scientific work related to meteorology and climate change in Brazil	Federal scientific agency

A set of common questions (table 8) were asked in each interview. The specific questions asked to some of the experts can be seen in the summary of each interview, included in the Annex 9.1.

**Table 8:** Common Questions for the Expert Interviews

- |  |
|--|
| <ol style="list-style-type: none"><li>1. What is missing to ensure that people are better adapted to drought?</li><li>2. What should be preventive measures to minimize losses due to droughts?</li><li>3. Are more policies needed? Or is it only a matter of implementing the existing ones?</li></ol> |
|--|

## 5. Results

The total number of performed group and individual interviews in each municipality, Itaocara and Santo Antonio de Pádua, is as follows in table 9:

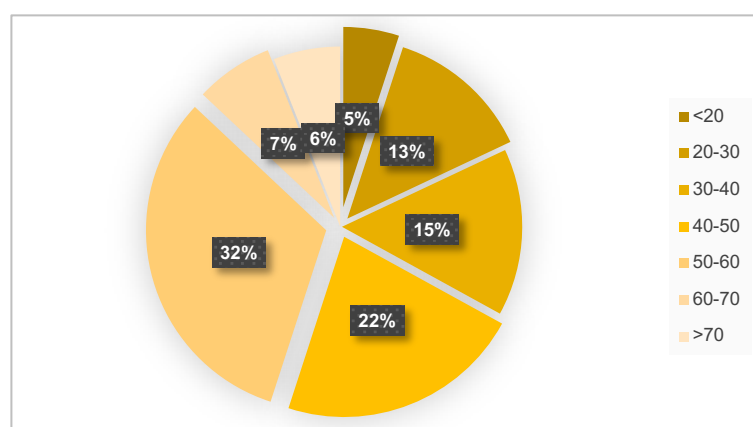
**Table 9:** Total Number of Individually Interviewed Farmers and Group Interviews

Municipality	Total Number of Individual Interviews	Group Assessments
Itaocara	36	2
Santo Antônio de Pádua	28	2
<b>TOTAL</b>	<b>64</b>	<b>4</b>

### 5.1 Individual Interviews with Producers

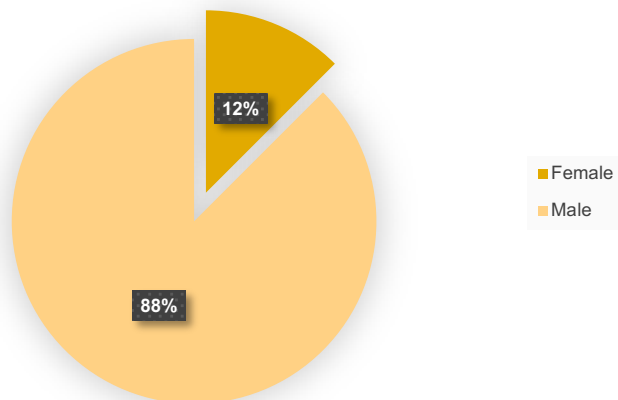
In this section, the results are presented as the sum of the interviews performed in both municipalities and in total percentages, except when specified.

A good proportion of the individuals interviewed (32%) were between 50 and 60 years old. Overall, the majority of the interviewees (67%) were over 40 years-old. This fact demonstrates a relatively old rural population in the study areas, as it can be observed in the figure 23.



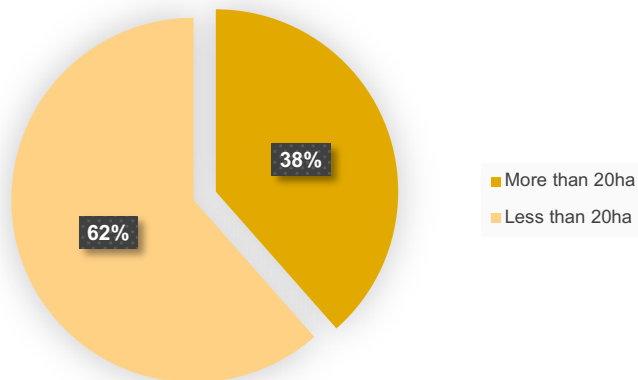
**Figure 23:** Age Range of Interviewees (n=64)

Most of the individual interviews (88%) were conducted with male farmers. In some cases, the wife followed the interview. However, they did not work directly in the farming activities so most of the interview was conducted with the male head.



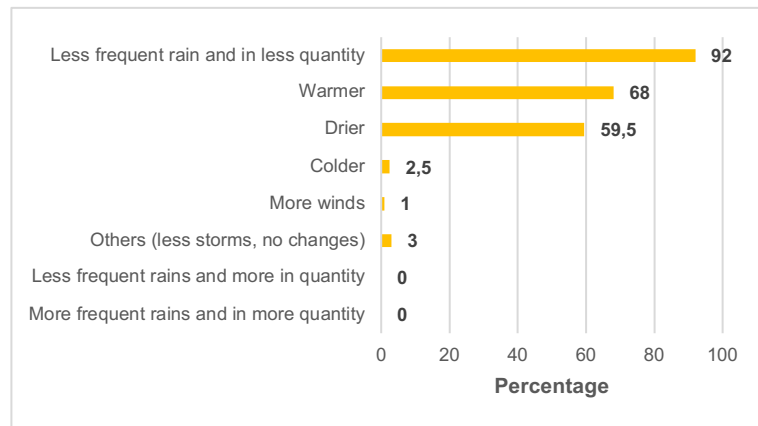
**Figure 24:** Gender Profile of the Respondents (n=64)

As expected, most of the interviewees (62%) worked on properties smaller than 20ha. For the standards in Brazil, they fall in the category of smallholder farmers. 93% of the respondents were property owners and 7% were leaseholders, in other words, farmers working on properties where they did not own. The overall percentage of farmers not living in the property was of 28%. These farmers usually had the residency in the urban area and they spent the day at the property and returned at night to their homes.



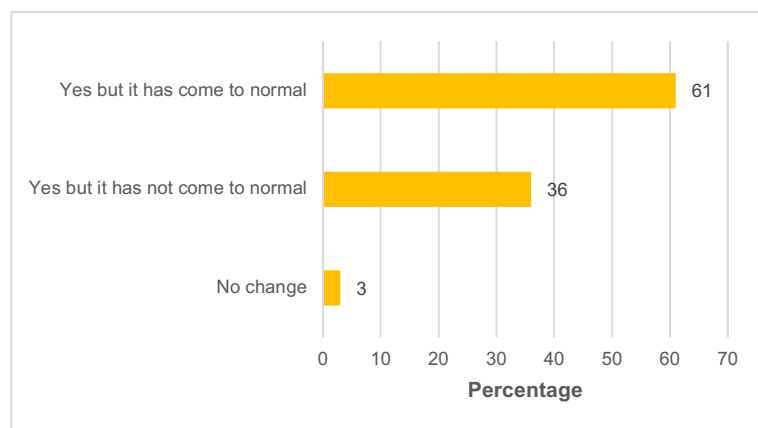
**Figure 25:** Percentage of Respondents with Property Size Larger or Smaller than 20ha (n=64)

As for climate change, the most common answer when asked what they perceive that has changed in the last few years with the climate change, the most common answer was that there is less rain in frequency and quantity, followed by higher temperatures and drier conditions.



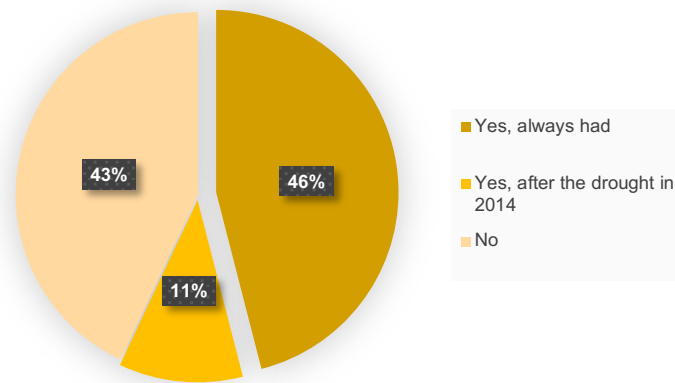
**Figure 26:** Perception of Climate Change Impacts among the Interviewees (n=64)

The observation of water availability in the property was very much related to their responses to the perception of less precipitation due to the changes in the climate. When asked if they observed changes in the water flow in the water springs in their properties, over 90% said they observed that the flow of their water springs decreased due to the drought. Out of this percentage, 61% of the total respondents noticed that the flow of water has come back to normal since the droughts, and 36% believe that the water flow has not come to normal (figure 27). 3% of the respondents claim that the water flow in their properties has not changed.



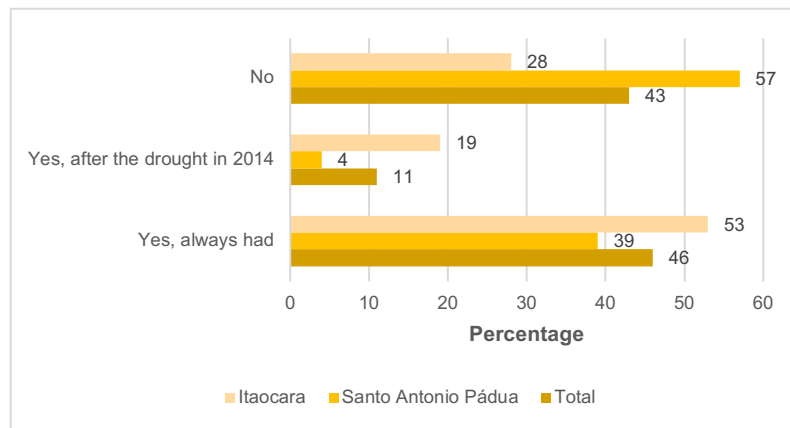
**Figure 27:** Perception of Changes in the Spring Water Flow Due to the Drought (n=64)

As the amount of rain decreases, farmers tend to get increasingly more dependent on irrigation systems. For this reason, farmers were asked if they had irrigation systems in their properties. In average, a high percentage of farmers have an irrigation system, in which 11% stated that they have it since the drought of 2014 and 46% said they already had the system before 2014. Surprisingly, 43% of the respondents answered they do not have irrigation system in their properties.



**Figure 28:** Percentage of Interviewed Farmers that Have Irrigation System in their Properties (n=64)

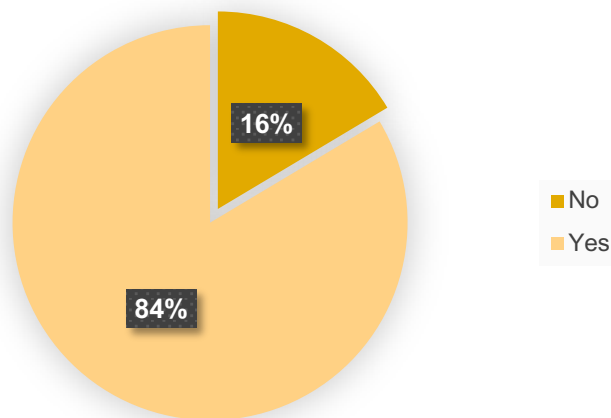
However, when analyzing the results in each municipality, the majority of the respondents in Santo Antonio de Pádua answered that they do not have irrigation system in their properties.



**Figure 29:** Percentage of Interviewees with and without Irrigation System in their Properties (n=64)

A question related to the importance of having preserved areas in the property was asked. The direct question regarding importance was included in the group interview, as it can be observed in the table 7. Participants of the group interviews unanimously agreed that having native protected areas in their properties is important and beneficial. This perception was confirmed through the individual interviews (84%), in which they positively answered to the question whether they had protected areas in the property.

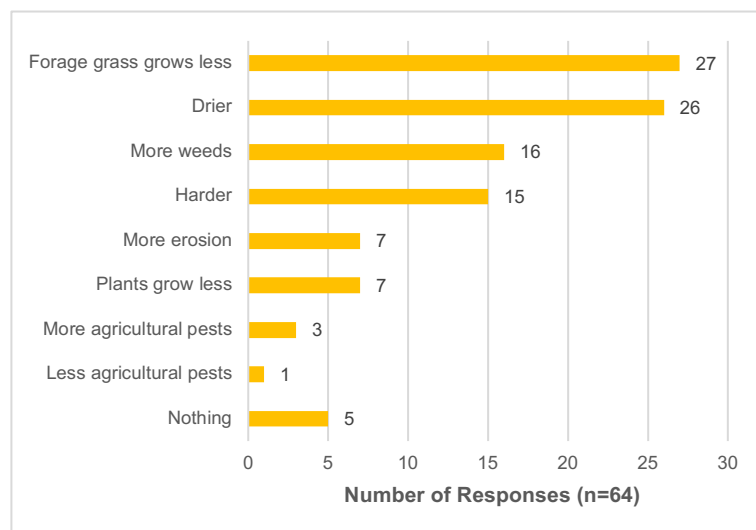




**Figure 30:** Percentage of Interviewees that Have Native Protected Area in their Properties (n=64)

Related to the perceived changes in the local climate, smallholder farmers were asked what changes they noted in the quality of vegetation cover and soil, specifically aiming to evaluate what the changes in provisioning and regulating soil ecosystem services have been as result of climate change.

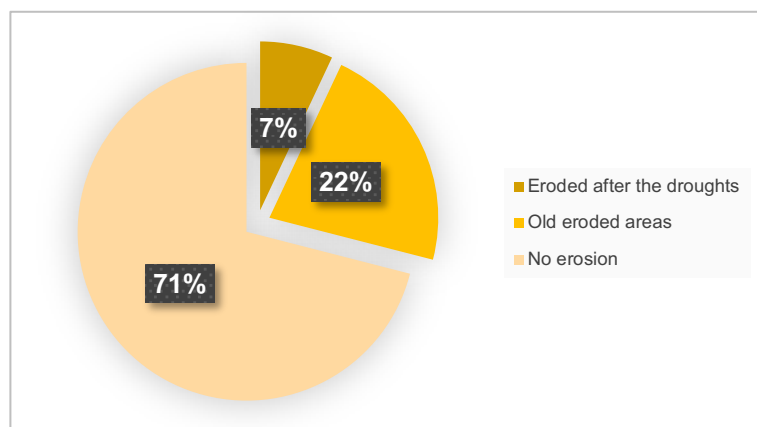
To answer this question, respondents were free in their answers. The following figure 31 presents the most common responses by number of respondents. The perception that forage grass grows less in size and quantity was the response with most answers followed by the perception that soil is drier, more weeds grow and harder to work at.



**Figure 31:** Most Answered Responses to the Question of Perception of Changes in Vegetation Cover and Soil Quality

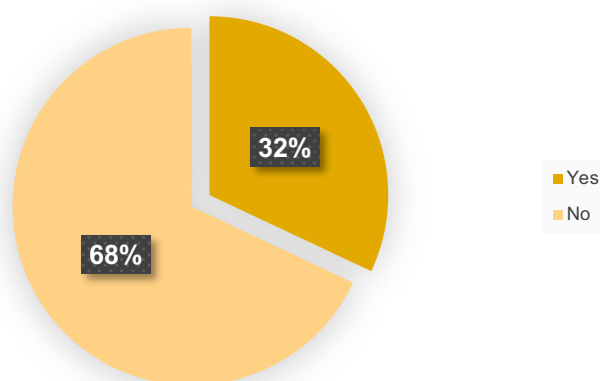
Considering that one of the perceived features in soil quality was the dryness, it was specifically asked if the respondents have eroded areas and if they have noticed more eroded areas since the droughts of the last years have been occurring. 71% of the total

number of interviewees claims that they do not have eroded areas in their properties. Of those that claimed to have, 22% answered that their eroded areas are old, having appeared before the climatic changes and only 8% affirmed that they have eroded areas that occurred due to the drought events.



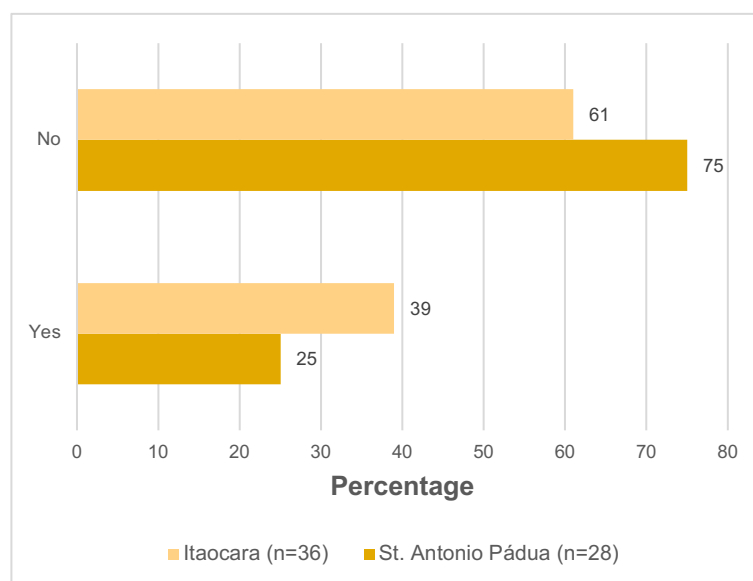
**Figure 32:** Percentage of Respondents for the Question Regarding Eroded Areas in their Properties (n=64)

For the evaluation of loss of soil fertility due to droughts, and therefore one of the provisioning soil ecosystem services, 68% of all respondents answered that they do not need to use more fertilizers due to the droughts. 32%, on the other hand, feel that the soil has become weaker and therefore the need of fertilizers has increased since the irregularity in the climate of the region.



**Figure 33:** Percentage of Interviewees that Perceive the Need of More Fertilizers after the Droughts (n=64)

However, there was a slight discrepancy between the answers obtained in Itaocara and in Santo Antonio de Pádua, as it can be observed in the figure 34. In Itaocara, the percentage of farmers that perceive the need of using more fertilizers is of 39%, against 25% in Santo Antonio de Pádua.



**Figure 34:** Percentage of Interviewees in Itaocara and in Santo Antonio de Padua that Perceive the Need of More Fertilizers after the Droughts (n=64)

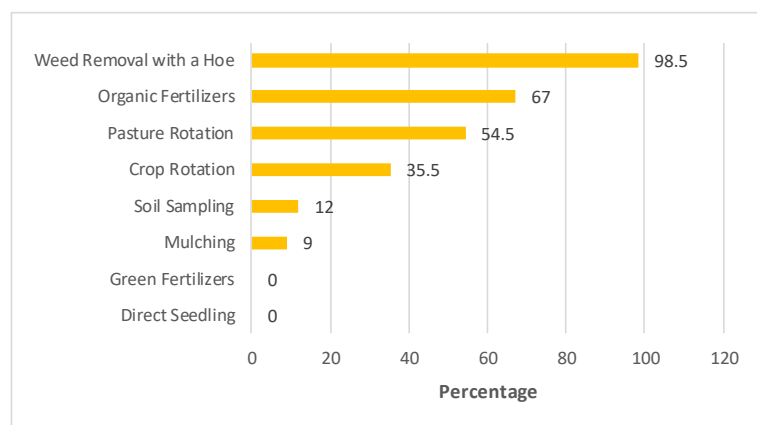
For the evaluation of the adopted ecosystem-based adaptation initiatives to protect the soil ecosystem and therefore guarantee the provisioning and regulating ecosystem services, most interviewees answered that they perform weed removal with a hoe and leave the remaining parts in the soil. No farmer declared the use of chemicals in the weed removal process. When asked if they used organic fertilizers, the majority of farmers claimed to use cow manure as fertilizer. Otherwise, no farmer claimed to use organic compost.

Many, though not the great majority of farmers who were interviewed perform pasture rotation, which was considered as answer if the farmer left their animals in different sides of their pasture land so giving time for the vegetation to regrow. The percentage was calculated over the total number of smallholder farmers who claimed to have livestock in their properties. Among smallholder farmers who claimed to have commercial crops in their properties, only 35% perform crop rotation.

Soil sampling, though a recommended practice by the EMATER technicians, is not usually performed by the farmers (12%) at a regular basis, neither by those who have commercial crops nor by those who make use of their area for forage production.

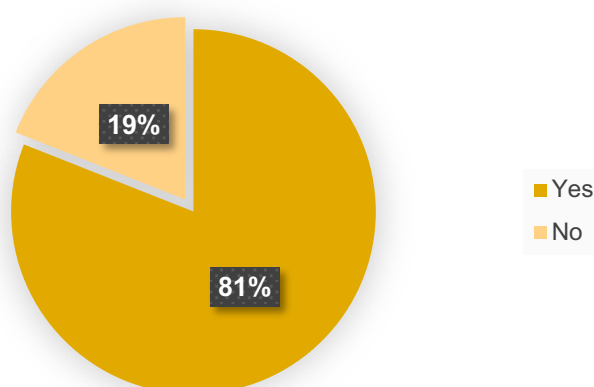
Mulching is a practice only performed by three smallholder producers who have introduced organic farming practices in their properties.

No farmer answered that they use green fertilizers or practice direct seedling.



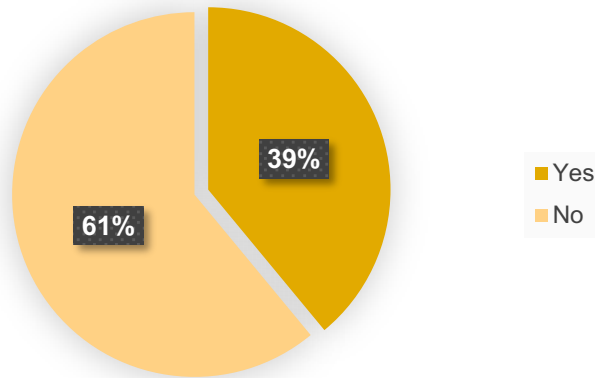
**Figure 35:** Percentage of Interviewees Adopting Soil Management Practices (n=64)

When analyzing the losses that farmers had in the last drought, in 2017, 81% of all farmers who have livestock for milk production (54 farmers in both municipalities) answered that the milk production decreased due to the drought.



**Figure 36:** Percentage of Producers that Claimed the Milk Production Decreased During the Drought (n=54)

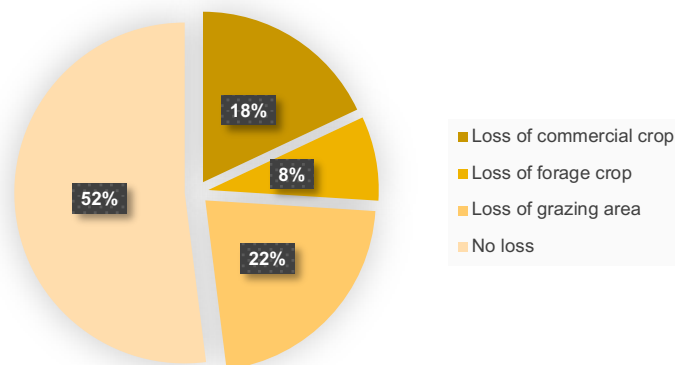
However, out of all producers who have livestock for milk production in the region, 61% claimed not having lost animals during the drought as presented in the figure 37.



**Figure 37:** Percentage of Milk Producers that Claimed Loss of Animals (n=60)

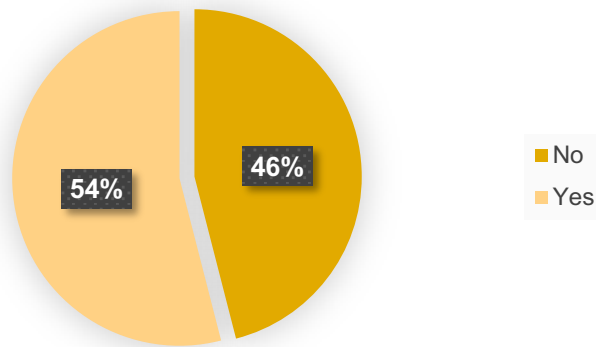
In regard to loss of productive area, most farmers (52%) claimed that with the drought they did not lose productive area. For farmers with commercial production, the question involved the loss of both commercial crops, eventual crop for forage and grazing area. For those with livestock only, the question was directed to the loss of forage crop and grazing area.

18% of those farmers with commercial production claimed to have lost production and 8% claimed to have lost crop for forage (grass or sugar cane).



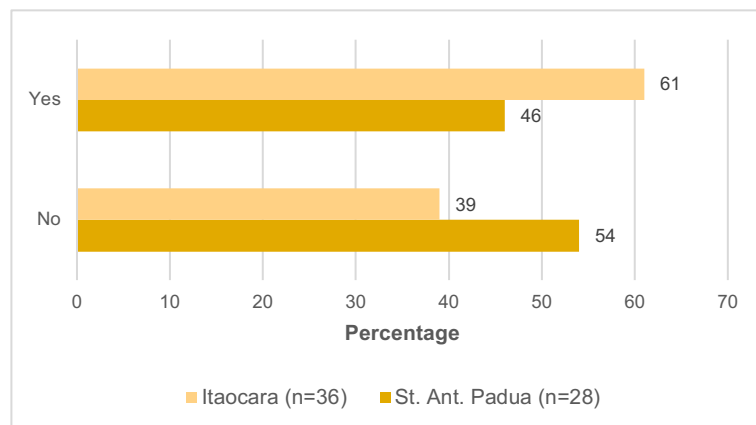
**Figure 38:** Percentage of Farmers who Suffered Losses During the Drought in 2017 (n=64)

In order to cope with the drought and avoid the loss of livestock, due to the impacts suffered during the drought, the average majority of the farmers (54%) needed to use personal savings to cope with the impacts.



**Figure 39:** Percentage of Interviewees that Needed to Use Personal Savings to Cope with the Impacts of the Drought (n=64)

However, this percentage is different between both municipalities (figure 40). While the majority of the interviewed farmers in Itaocara answered that they needed to use personal savings (61%), in Santo Antonio de Pádua it was the opposite. 54% of the interviewees in the municipality claimed they did not need to do so.

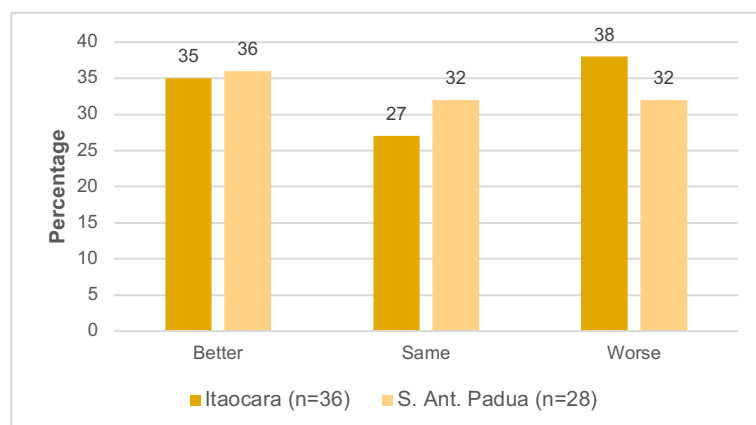


**Figure 40:** Percentage of Respondents that Needed to Use Personal Savings to Cope with the Impacts of the Drought in each Municipality

In the context of evaluating adaptation and limits to coping capacities, interviewees were asked how they think their livelihoods would be if there was a drought again in 2018. In both municipalities, the percentage of interviewees that believe that if there is another extended dry period leading to drought in 2018 is similar (35 and 36%). In Itaocara, the percentage of respondents that believe that their losses will be the worse due to their ability to cope with an eventual drought is slightly higher (38%) than in Santo Antonio de Pádua.

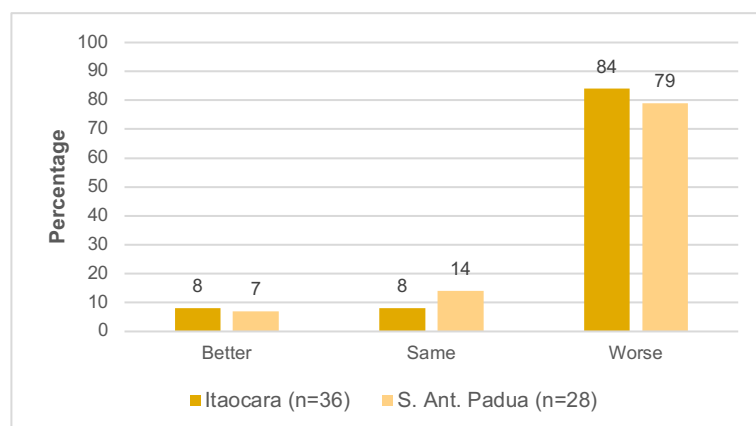
In Santo Antonio de Padua a slightly higher percentage of respondents (32%) believe that their abilities to cope with the drought and the impacts that will affect them personally, of an eventual drought will be the same as in 2017.

The figure 43 shows the results, in percentage over the total number of respondents.



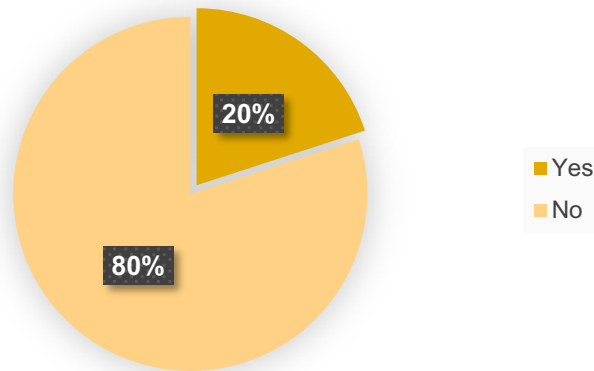
**Figure 41:** Responses to the Livelihood Situation in Case of Another Drought in 2018

When questioned how it would be for the interviewees if there was drought every year, similar to the one that occurred in 2017, the majority of the respondents in both municipalities answered that for them, in relation to their losses due to lack of adaptation and coping abilities, would be worse than their actual situation. The comparison of the results of both municipalities is presented in the figure 42.



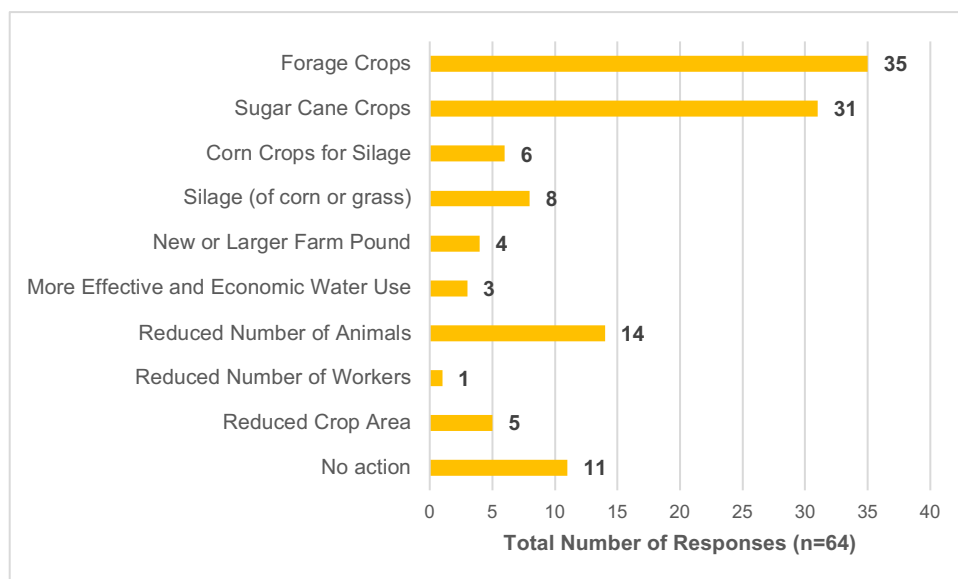
**Figure 42:** Percentage of Responses for How It Would be for the Farmers if there was Drought Every Year

Considering that most respondents believe that the conditions in their properties would worsen if the droughts become regular, it was asked if they would consider leaving the property permanently. Despite knowing that farming could get more difficult, 80% of the total respondents (n=64) would not consider leaving their properties and migrate to the city.



**Figure 43:** Percentage of Responses for the Intention of Leaving the Rural Area Permanently if Droughts Become Regular (n=64)

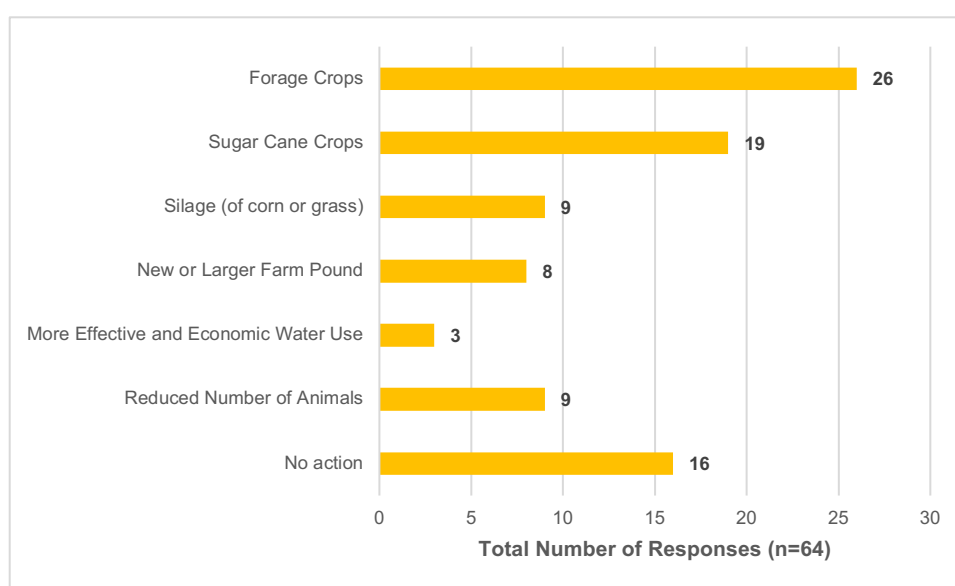
As the respondents are aware that if droughts become regular and in spite of it they would still choose to remain in their properties it was questioned what they have been doing to get prepared for an eventual and unexpected drought, since the last event in 2014. Multiple answers were possible, and the figure 44 shows the results for the responses in both studied municipalities. The most common practice adopted by the farmers in adapting to the drought is planting more forage for feeding the cattle during the drought (35 answers). Second practice, very similar to the first one is planting sugar cane, also for feeding the cattle (31 answers). Many farmers also claimed reducing the livestock so that the maintenance during hard periods can be lightened. Interesting that though losses due to drought were severe, there were farmers responding that they have done nothing nor taken any action to get prepared for the drought.



**Figure 44:** Practices for Preparedness for Eventual Droughts, Adopted since 2014 (Multiple Answers were Possible)



Though many respondents claim that since 2014 they have been adopting practices to enhance resilience against drought, figures 37 and 38 show that there were losses due to the drought and the need of using personal savings (figures 39 and 40). Considering that the last drought was in 2017, farmers were asked what actions they have been taking to get prepared for an eventual drought in 2018 (figure 45). Forage and sugar cane production were expected as answer since these are the main measures taken since 2014. New to the list of measures since the last drought is the adoption of silage practice in the properties. There is also a slight increase in number of respondents that claim not taking any preventive measure to prepare for an eventual drought (16 responses).



**Figure 45:** Measures Taken to Prepare for an Eventual Next Drought

## 5.2 Group Interviews

Table 10 presents the questions and the results of the group assessments performed in both municipalities. The questions were semi-structured, and the answers presented in the following table were the most agreed ones among the respondents during the assessment. In total there were four assessments, two in each municipality. Group sizes varied, though they were of minimum eight and maximum 25 participants.

In relation to the changes in the climate, in all assessments it was commonly agreed in recent years it has become dryer than usual and that it rains less the whole year.

Concerning the soil of the region, it has become harder to work at and more fertilizers have become needed, as climate has changed and caused alterations.

However, participants do not see more eroded areas than the existing ones.

In general, since the changes in climate and drought in 2014, in both municipalities smallholder farmers are producing more forage and sugar cane to ensure fodder for the livestock.

As most of farmers have a preserved area in their properties, it was asked if they feel it is important to have preserved areas. They all agree that preserved native areas are important for the climate quality and ensuring water recharge in their water springs.

Though the groups claim to have adaptive measures, they all feel that if there is another drought in 2018, quality of soil, their means of livelihood and financially for all the community will become worse than it was as result of the 2017 drought. In the assessments it was agreed that migration to the urban area might be necessary to ensure financial income.

When asked what they fell it is needed to improve their resilience and adaptation to drought, all agreed that they individually lack the financial resources, so they feel government should make them more financial resources available (more money).



**Figure 46 and 47:** Group Interviews in Itaocara and in Santo Antonio de Pádúa

**Table 10:** Questions and Results of the Group Assessments in Itaocara and S. Ant. de Pádúa

	Itaocara	Santo Antonio de Pádúa
1. Do you notice changes in the climate? Have the seasons changed?		
Shift in the dry and rain season	++	+
Drier than usual	++	++
Less rain all year	++	++
2. Because of the droughts, what has changed in the soil?		
Harder	++	++
Drier	+	+
More erosion	+	+
Need more fertilizers	++	++
More weed growth		+

3. How about erosion? Has it increased in the region?		
Yes	+	n.a
No	+	++
4. What has been done to adapt to droughts since the last one in 2014?		
More forage and sugarcane crops	++	++
Less animals and crops	++	+
More alternative water supply (ponds, water wells)	++	+
5. Do you consider important the preservation of native areas?		
Yes	++	++
No	n.a	n.a
6. If there is drought every year, how will it be (better/same/worse)?		
Better	n.a	n.a
Same	n.a	+
Worse	++	+
7. If there is drought this year again, how will it be (better/same/worse)?		
For the local economy	Worse	Worse
For the community	Worse	Worse
Unemployment	Worse	Worse
Need for migration	No	Yes
8. What is needed to ensure resilience to drought?		
More money	++	++
Incentives such as cheaper fodder and energy for producer	++	+
Technical assistance/ capacity building	n.a	++
More technology available	n.a	+

⊕ Important issue (Answer was given in one assessment)

⊕⊕ Very Important issue (Answer was given in two assessments)

n.a - Answer was not mentioned in the assessment

### 5.3 Expert Interviews

Two local, three regional and one national expert were interviewed with the purpose of gathering information about the drought in the study area and the gaps in the adaptation process. A summary of each interview is in the Annex 9.1.

At the local level, both experts from each municipality points out the need of awareness-raising among farmers. Farmers need to be informed of the importance of building up resilience for drought. They also point out the need of more policies to ensure prompt support to farmers during the drought. Both local experts that were interviewed mentioned the advantages of the agricultural measures that were enabled through the funds of the Rio Rural Program. However, the results of this study demonstrate that though these measures might be beneficial for the development of sustainable practices and improve resilience to drought, still much has to be implemented to improve resilience.

At the regional level, experts cite the question of awareness-raising and change in behavior in order to ensure better adaptation. Two of the interviewed experts are directly involved in the Rio Rural Program and they were positive about the outcomes of the project. However, both agreed that the program needs continuity and due to the political uncertainties the following up of the program is very uncertain.

As the national expert is a climatologist, for him, the local impacts cannot be fully attributed to global climate change. There are many variables in the local climate that make it difficult to attribute the latest droughts to global climate change. For the same reason it is difficult to predict the future changes at the local level. The lack of information and monitoring are fundamental for these predictions, which is been worked on. However, it will take time until modellings for the future establishment of early warning systems for local impacts can be implemented. As immediate adaptation measures, the expert sees the necessity of more technological alternatives to adaptation, such as in the development of new and more resistant crop resistant species. The expert also mentioned the need of political willingness to ensure that farmer adapt and not only build up coping capacities.

## 6. Discussion

The purpose of the study was to analyze the perception of climate change and adaptation to climate change, especially in regard to ecosystem-based adaptations to ensure the quality of provisioning and regulating soil ecosystem services. The following sections specifically discuss the details of the findings and how they fulfill the objective of the study.

### 6.1 Sampling Observations

Respondents were chosen according to their availability and willingness to be interviewed. There was no target group and the only criterion was to be a rural producer in a property within the studied municipalities.

Women are minority in the farming business in Brazil. Simões and Mattos (2010), cited by Schneider (2016), argue that the number of households in Brazil headed by women was of approximately 30%. Nevertheless, the overall percentage, 30%, is still very low. For this reason, it was expected to find and interview a low number of women that were head of the farming property. In fact, only 12% of the interviewees were females. None was the head of the family; they were wives who worked in the property along with the husbands.

### 6.2 Perception of Climate Change

The results of this study demonstrate that smallholder farmers do perceive changes, and the clearest sign for them is the less rain in frequency and quantity. Consequently, it is drier. They also notice that it is warmer than it used to be. Many farmers perceived the changes in quantity of rainwater as the availability of water in the spring water has changed.

Though many observed changes in the water flow due to the drought, most of them have also noticed that the flow has become normal again as the rain season began. There were accounts of farmers who believe that the flow of spring water used to be much more abundant and this decrease has been gradual over the years. However, this fact has to be carefully considered, as a thorough land use study has not been made in the area and therefore changes in water availability may have other causes rather than only climate change.

### 6.3 Changes in the Soil Provisioning and Regulating Ecosystem Services

Through the indicators in which provisioning and regulating soil ecosystem services can be measured, when analyzing them, it is possible to observe that farmers perceive changes in both the provisioning and in regulating services.

Soils are harder, so they do not provide water. If forage grass is perceived to grow less, it evidences that soils are weaker so the provision of nutrients is compromised. According to Dominati et al. (2010), soils enable plants to grow by providing physical support, water and nutrients. Therefore, if soils are dry, plants grow less, and it has been perceived the need of more fertilizers after drought periods (figure 35), one can infer that the droughts and even the constant climate change compromises these ecosystem services. However, other variables such as farming practices and land use might need to be taken into consideration.

In Santo Antonio de Pádua the number of farmers that claim that notice the need of using more fertilizers after droughts is greater than in Itaocara (75% against 61%). Reasons to explain this difference cannot be pointed out based on the results of this study.

In the group assessment, participants also pointed out soil dryness and hardness as features to be observed due to the changes in climate. It was also mentioned the increasing weed growth, which could also indicate lack of fertility as the grass/crop does not grow and the area is taken over by weeds.

Despite farmers noticing that the soils have become drier and harder to work at, they claim that no new eroded areas have appeared in their properties after droughts. Similar response was obtained during the group assessments. In Santo Antonio de Pádua, in both assessments participants answered that the area did not suffer with erosion.



**Figure 48:** Example of Eroded Area in a Property in Itaocara

Most farmers with eroded areas in their property (71%) claim that these eroded areas are old and not resulting from droughts. It can be inferred that the erosion-control regulating service is not affected, though the fertility of the soils has been noticed. However, one could argue that precipitations have not been enough to cause washings during the raining season.

Changes in fertility may also have origins in compromised regulating services such as filtering nutrients and recycling of organic wastes as these services also ensure provision of nutrients to plants.

During the field visits for the interviews, it was observed that some farming practices are not ideal for soil conservation, as exemplified in the figure 49, which shows the preparation of a sloped area for seedling. In the picture, the unprotected soil leaves it prone to wind impact and eventual rain-washing, which could lead to loss of fertility and erosion. Therefore, erosion might be a problem that might occur in the long term, having other contributing factors, rather than only climate change, as causes.



**Figure 49:** Soil Preparation for Seedling in a Sloped Area in Itaocara

In general, farmers do not perform the soil analysis, which is fundamental to support the decision of which and how much fertilizers and soil correction is needed (Stivari et al. 2014). Nitrogen fertilizers tend to acidify the soil, so correction is needed (Isherwood, 2000). Therefore, whether fertilizers are used in excess or not in enough quantity is a factor that influences fertility. As producers do not perform soil analysis, they do not know the soil properties and therefore whether the provisioning and regulating ecosystem services in the study area are used in its optimum or if they might be compromised.

#### 6.4 Protection of Native Areas

Nehren et al. (2017) discuss the importance of the fragments of native forests, in such that connectivity of forest fragments in the northern area of Rio de Janeiro is important, as to ensure the maintenance of biodiversity and positively influence human well-being.

Moreover, Follmann and Foletto (2013), in studying a preserved area in Brazil, evidenced that the preservation of native forests is fundamental for the recharge of underground aquifers and consequent influence on superficial waterbodies.

Farmers in the region agreed that having native protected areas in their properties is beneficial, the fact that most respondents have protected areas confirm it. However, there are two reasons for such.



First, according to the National Forest Code<sup>7</sup>, farmers had to declare until 31 May 2018 that they had at least 20% of the total size of their property in the form of a native or restored forest protected area. Therefore, it has become mandatory to have protected forests in the properties. Second, one of the requirements for submitting projects for funding in the Rio Rural Program, according to information obtained with EMATER technicians, farmers needed to have a protected area or submit a project requesting funds for fencing an area to be protected in the property.

Though through the EMATER technical staff farmers were instructed about the importance of having protected forests in the property for the maintenance of water availability, there were reasons other than just conservationist ones for the producers to have protected areas in the property.



**Figure 50:** Protected Native Area in a Property in Itaocara

## 6.5 Soil Ecosystem-based Adaptation

The soil management practices adopted by the farmers are the main indicators of practices that not only ensure the quality of the soil ecosystem services and its conservation, but they also help build up resilience of the environment and sustainable economic gain to the farmer. However, these are not the only climate change adaptation practices adopted.

All the practices related to soil management, that are adopted to deal with the changes due to the droughts cited by the farmers in this study, were analyzed and classified based on the three dimensions defined by Vignola et al. (2015). The detailed description of each dimension can be found in the section 2.4.

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<sup>7</sup> National Forest Code or Native Vegetation Protection Law no. 12.651/2012 (source: <https://www.redebrasilatual.com.br/ambiente/2018/03/meio-ambiente-sai-perdedor-com-o-novo-codigo-florestal-diz-especialista>. Accessed 14 August 2018)



The categorization into each dimension was made based on the benefits for the farmers of each adopted practice and the popularity of the practice, according to the answers from the individual and the group interviews. The result of the analysis is presented on table 11.

**Table 11:** Classification of the Adaptation Practices Related to Soil Management, Based on the Dimensions Described by Vignola et al. (2015)

Practice	Dimension 1 (ecosystem-based)	Dimension 2 (adaptation benefits)	Dimension 3 (livelihood security)	None
Weed removal with hoe	x		x	
Organic fertilizers	x	x	x	
Pasture rotation	x	x	x	
Crop rotation	x	x	x	
Soil sampling		x	x	
Mulching	x	x	x	
Forage crops	x	x	x	
Sugar cane crops	x	x	x	
Irrigation system	x	x	x	
Protection of native vegetation	x	x	x	
Conventional fertilizers				x



**Figure 51:** Example of Area Divided for Pasture Rotation in a Property in Santo Antonio de Pádua



**Figure 52:** Tomato Production with Dripping Irrigation System in Itaocara

According to Vignola et al. (2015, p.128), “practices that substitute the role of biodiversity in providing ecosystem functions and services such as inorganic fertilizers or fungicides are not ecosystem-based.” Therefore, in adopting the use of conventional fertilizers, this practice cannot be classified as ecosystem-based.

Capeche (2012) argues that the biomass burning (living or dead vegetation), exposes the soil to weathering condition such as rain and winds, which can cause erosion. It also reduces soil biodiversity and organic mass, compromising the fertility. All farmers that responded they remove weed with a hoe were asked whether they practice biomass burning. They all answered they do not adopt such practice. Also, the harvest of the sugar cane is done manually. The non-adoption of biomass burning practice can also be considered an additional positive practice for soil conservation.

The other adopted practices that do not match in any of the three dimensions above (reducing the cattle, use of personal savings and leaving the rural area), are rather coping measures to deal with impacts of drought. Considering the definitions of coping and adaptation presented in the table 2 in section 2.5, these three practices are oriented towards survival, they are short term and not continuous. They do not ensure the economic stability of the farmer in the long term. Therefore, they are not adaptation to climate change practices.

## 6.6 Other Adaptation to Climate Change Practices

Other practices to adapt to drought were claimed to be effective practices in water use (3%), such as pumping water for irrigation only at certain hours of the day rather than pumping it continuously, increasing size of the pond for water storage and reducing crop area and/or number of animals. These three practices were claimed having been implemented since 2014 and some farmers answered that they will continue or even enhance the practice

following the 2017 drought. Considering that they are not new, it seems that they were not well applied as adaptation practices, as they still suffered losses due to the drought.

Also, in the group assessments, participants also responded that as adaptive measure, they are increasing crop area for forage, reducing number of animals and commercial crop and searching other water supply alternatives such as opening new water wells and increasing artificial ponds for water storage.

A number of respondents (11 respondents out of the total of 64) answered that they have been doing nothing to prepare for the drought since 2014, and neither are doing anything for the eventual next drought (16 respondents out of 64). This fact infers that an eventual next drought will cause further economic losses to the farmers in the region.

## 6.7 Financial Losses

81% of the farmers who have livestock for milk production claimed that the production decreased due to the drought. Though the situation was extreme, however, the majority (61%) said that they did not lose animals during the drought. Farmers had a loss of income during the drought as result of the impacts. However, those who did not lose livestock could ensure survival after the drought, even though it costed them the use of personal savings. Still, the percentage of farmers who lost animals along with the loss of production is over a quarter of the total (39%), which means that drought might have had a significant economic impact in the region.

Due to the fact that even the municipalities had emergency decrees due to the drought and that the loss of farmers affected the local economy, it would be expected that risk financing measures should have been implemented in the area to support farmers to cope with the drought. However, the study evidenced that farmers only had their personal savings as financial source to deal with the droughts (56%). Taking the table 3 (section 2.5.1) into consideration, which describes the different risk mechanisms (risk retention, sharing, transfer), one can infer that farmers are still at the risk retention level, in which they financially deal with the losses at the individual level. As there are no community funds or disasters funds available, farmers have no other option. The first problem of individual risk retention is that, first, it is a mechanism to deal with losses due to low impact events that happen with a certain frequency. As we can see, the droughts in the study area have become frequent since a few years (first 2014, then 2017). As the municipalities had emergency decrees for the drought periods, it could be inferred, however, that they are not considered low impact climatic events.

Second, it is a coping strategy that can lead to long term impacts in the quality of livelihood of the farmers and limit economic growth (Chantararat, 2015).

There was a difference between the municipalities of Itaocara and Santo Antonio de Pádua, having most of the interviewees in Santo Antonio de Pádua claimed that they did not need to use personal savings to deal with the impacts of drought and yet the animal losses among the interviewed farmers was not significant (only 25% claimed loss of animals due to the

drought). This might be related to the fact that most farmers in the municipality do not have commercial crops, less livestock for milk production and more cattle for beef than in Itaocara. However, this study has not gathered enough information to explain the reasons for this difference.

## 6.8 Limits to Adaptation and Migration

The study was performed in the months of May and June 2018 and the last drought period registered in the region was in 2017. Therefore, farmers could recall very well the impacts of the event and the actions taken to cope with them. When the interviewees were asked how it would be if there was a drought again in 2018, the answers were mixed. Many felt that they have been preparing for a drought, so they believe that their financial situation, quality of soil and their adaptive measures are good enough to go through another drought (35% in Itaocara and 36% in Santo Antonio de Pádua). 38% of the respondents in Itaocara and 32% in Santo Antonio de Pádua feel that if there is another drought in 2018, their situation, in special their financial one, will be worse than it was in 2017. According to the figure 47, many answered to be preparing for the next drought. When asked how the interviewees feel it would be if the drought becomes regular every year, a significant majority (84% in Itaocara and 79% in Santo Antonio de Pádua) feel that situation (quality of soil, personal finances, resilience of adaptation practices) will be worse than it has been with the last drought.

Responses were similar in the group assessments. Participants claimed that if drought occurs again, either in 2018 or if it becomes regular, community losses in terms of economy and life quality will worsen.

When asked if respondents were willing to leave the rural area due to the drought, surprisingly 80% of the respondents would not sell the properties and leave permanently. Most of them claimed that the properties were inherited and passed from one family generation to another, so there is a sentimental bound between the smallholder farmers and their land. Those who have left the rural area for the urban areas have already done so for reasons such as lack of schools for the young generation or lack of interest in farming. No farmer claimed having acquaintances that left for the urban area due to the climate change.

The discrepancy in the answer between readiness for another drought and for a permanent change in the scenario indicates that the measures taken by the farmers are coping capacity preparedness rather than long term adaptation to climate change measures. If the measures such as forage production and silage were planned as adaptive measures, farmers would become to be more prepared for a permanent change.

Farmers claim that since 2014 they have been adopting a series of measures (figure 44). Still, these measures lead to loss of production and even animals and the use of personal financial resources was needed. The measures adopted since 2014 are not enough for them to cope with climate change.

## 6.9 Preparedness for the Future Droughts

Interviewed farmers claim that for the next drought they are mostly growing more forage and sugar cane field to ensure fodder for the livestock. Most claimed that they have been doing so even before the drought in 2017, and as the produced quantity was not enough, they have decided to increase the crops. If on the one hand farmers increase the production for fodder, on the other hand, many also claim to decrease the number of animals. Farmers did not cite having technical knowledge or the support to make the correlation between the quantity of fodder, eventual needed size of forage production and number of animals so that they could better plan how much crop is needed for the quantity of animals. As in 2017 farmers had loss of production and even of animals due to the scarcity of fodder, it is evident that forage production as adaptation practice was either not effective or not enough to avoid economic losses.

Torres (n.d.) argues that in setting a sugar cane field the variety of the sugar cane has also to be considered, along with soil fertility and plague control. Corrêa and Santos (2003) present the difference among different species of grass of the genres *Panicum*, *Brachiaria* and *Cynodon* and the differences in cattle feeding in pasture with these different grasses. For Araujo (2016), the choice of grass species production for forage has to be made taking the soil and climate conditions into consideration. Therefore, it has to be evaluated whether the type of sugar cane and grass forage planted in the region are the ideal ones for the climate and soil condition of the region and ideal productivity.



**Figure 53 and 54:** Example of Forage Production and Area for Silage in Itaocara

Though a small percentage of producers (8%) claimed to have lost commercial crops, it has also to be evaluated whether the plant varieties or even the type of crops are the ideal ones for the local climate, its variability and eventual water scarcity.

These decisions demand technical support that the farmers need to have in order to become more resilient to droughts.

## 7. Conclusion

In line with the theoretical findings, the smallholder farmers in Itaocara and Santo Antonio de Pádua perceive the climate changes by observing the decrease in rainy days, decrease in quantity of rain increasing number of warmer and drier days. The droughts that affected the region in 2014 and again in 2017 comply with these perceived changes in the climate patterns.

The climate pattern is very similar in the area, as judging from the precipitation information officially taken from Itaperuna and compared to the precipitations measured in Itaocara and Santo Antonio de Padua. However, there were discrepancies in the results of some of the findings related to adaptation and coping practices in both municipalities, such as the need to use personal savings due to drought impacts or adopting the use of irrigation system in the property to cope with rain scarcity. This leaves a recommendation for further research in other municipalities so that a more exact picture of the practices adopted to deal with drought due to climate change in the Northwest region of the state are and the extent of these impacts in the soil provisional and regulating ecosystem services. The findings of this study cannot fully present the situation in the whole region.

Farmers have noticed changes in the soil quality, which affect the soil provisioning and regulating services. The main affected provisioning service is related to the provision of food, as evidenced by the fact that farmers need to use more fertilizers in order to produce more fodder and for the commercial production.

Erosion could not be measured as a result of loss of supporting service due to drought in this study. However, if there is a loss of fertility, there might be changes in the soil cycling systems that affect fertility and thus its supporting service.

Nevertheless, changes in these soil ecosystem services might have various causes. This study is preliminary and based on perception, which means that further investigation for evidencing, for example loss of fertility and the probability of erosion in the future, has to be conducted so to analyze whether climate change plays an important role in these changes or not, along with other anthropogenic drivers, such as land use and farming practices.

Farmers have adopted measures to adapt to what they perceive as changes in the climate. Some of these adopted measures are beneficial for the soil environment and also help them overcome the impacts of climate change. Therefore, most are classified as EbA practices.

However, it has also been evidenced that these practices do not ensure enough adaptation to avoid losses in the periods of drought. Though many of the practices have been adopted since or even before the 2014 drought, in 2017, farmers had significant production loss. This means that the practices must be evaluated, and new ones have to be added to the actual ones. Decisions such as the type of grass for forage, farming technique improvement and the availability of crop alternatives that ensure soil protection and resilience to droughts are gaps that need to be dealt with.

It was noticed that the rural population is overaged and that farming practices are getting more and more difficult due to the physical limitations of farmers. Though farmers are aware

of the severity of impacts if droughts become regular, the majority would not leave the rural area. It demonstrates that in the future the smallholder farming practice might disappear in the region, being climate change one of a number of factors. A correlation between the average age of farmers and ability to adapt could not be done in this study. These might be important to evaluate what the needs are to ensure resilience for the rural aging population.

The challenges presented in the Brazilian National Adaptation Plan (section 2.2.1), in regard to risk transfer seem to be the challenges present in the study area. There is no risk transfer mechanism that could financially support farmers for building up resilience. Farmers present a lack of technical knowledge so that practices for managing the soil properties are minimal and not enough to ensure sustainable development. The state governmental program, Rio Rural, that was created with the objective of supporting the implementation of sustainable farming practices that also enable climate adaptation practices has come to an end. This is critical as it has been noticed that despite the implemented practices, farmers still suffer losses during drought periods.

Though the National Adaptation Plan foresees the implementation of actions to build up resilience through the National Plan for the Reduction of Risks and Disasters, this plan does not include actions related to drought. Therefore, there is a gap in the priority of actions related to minimizing impacts of drought, so more policies are needed to ensure that drought in the Northern area of Rio de Janeiro State is considered a serious and impacting event.

There is no early warning system for the region. As cited by one of the experts, the CEMADEN does not yet work with the monitoring of droughts in the Southeast of Brazil. This compromises the ability to prepare for the droughts beforehand. The precipitation data of both municipalities (Annexes 9.2 and 9.3) were obtained with local producers, who kept the readings up to date. However, their data is not used for analysis. Data is in some areas available and could be used for modelling and predicting future events. Therefore, there is the urgent need of considering a larger meteorological network system that can support the prediction of climatic future events at the regional level. The NAP implementation report cites that measures related to the improvement of scientific knowledge to enhance resilience have been implemented and that in the agricultural sector climate for agriculture monitoring systems have also been implemented. However, no action related to improvement of monitoring system or early warning system for drought have been noticed in the study area.

The improvement of the climate monitoring system is one of the priorities of the NAP. It needs to be ensured that information reaches the local level.

In relation to the limits to adaptation, this study has not gathered enough information to evidence the limits to adaptation. Even though some adaptation to climate change practices have been adopted (such as the EbA practices already discussed), they do not ensure long-term resilience. Therefore, there was not enough data to evidence the local long-term limit to adaptation. More investigation is needed to find out the limits, especially financial. As farmers have limited individual resources, this may not be a driver to long-term adaptation, but a danger for them to fall into the poverty loop, if constantly used as coping measure.

The first hypothesis of this study has been evidenced to be wrong, as smallholder farmers have not implemented adaptation measures to drought between the drought in 2014 and the last one in 2017.

The second hypothesis, that due to their adaptation practices they did not have financial losses in 2017 is also proved to be wrong, as farmers did not adapt well enough and therefore had losses and even needed to use personal resources.

The third hypothesis could not be validated either. It has also been proved wrong. But in this case, the hypothesis could not be validated due to lack of sufficient information. Most interviewed farmers live and work in their properties, and as most of them own livestock, there is no work seasonality. Oral accounts indicated that reasons for migration might not be climate related, but to schooling of children and better job perspectives for young people in urban areas. A more detailed research, specifically in migration and its causes, need to be conducted in the area so to validate the hypothesis of whether migration has climate causes and is therefore a coping measure or an adaptation measure.

The expert interviews also indicate that there is a lack of capacity building so that better technical support can be delivered to farmers. Lack of financial resources and political willingness to implement measures are also gaps that need to be dealt with so that the farmers can build up adaptation to gradual changes that have been happening in the local climate and not only preparedness for disasters, the short-term coping measures.

The findings of this study identified that there is a general lack of information about climate change, drought and adaptation at the local level. The technical EMATER staff is aware of the necessity of improving agricultural practices, but as means of building up financial resilience. Both technicians and farmers need to become more aware of the importance of environmentally sustainable practices for the protection of soil ecosystem services and resilience to future droughts.

Financial mechanisms also need to be implemented for better support and to build up resilience. For all, more policies are needed to ensure that adaptation to climate change becomes part of smallholder farmers in the study area. Capacity building is needed so that the EMATER technicians are better prepared to support the farmers in improving their adaptation practices to ensure better future resilience to droughts.

Changes in the regional climate and the increasing frequency of droughts in the study area are likely to occur in the future. The study has pointed out some of the issues that need to be dealt with, at the local, regional and national levels in order to ensure that local smallholder farmers become resilient and adapted.



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## **9. Annexes**

## 9.1 Expert Interviews

### **Regional Expertise:** Itaocara

Date: 24 May 2018

Place: EMATER's office, Itaocara

Expert: Mr. José Matias Rocha – Head of the EMATER's Itaocara Office

- *What is missing to ensure that people are better adapted to drought?*

There is the necessity of awareness-raising about the problem. Farmers are too laid back and they do not have a sense of community, being too individualists. They do not do enough to help themselves. Changing the mentality of farmers cannot be done by the EMATER technicians alone.

The government at all spheres (municipal, state and federal levels) have to act to ensure that farmers feel better supported and they can implement the actions to adapt.

On the governmental level, there is awareness, but it still lacks the implementation of public policies to deal with drought. Some farmers are acting, but we need more policies so that their actions can be better organized and.

The municipal authorities need to get more involved in the local issues. Local politicians are still very old-fashioned so changes are difficult to get absorbed and implemented.

- *What should be preventive measures to minimize losses due to droughts?*

Producers only change when their incomes change. Payment for ecosystem services, for example, could benefit producers and motivate them to enhance the practices of water storage and alternative intakes (artificial ponds, terrace farming). Cooperatives should also improve themselves so that they can offer better support to their associates.

- *Are more policies needed? Or is it only a matter of implementing the existing ones?*

Maybe it is not the specific policies that are needed. Some policies in other sectors might be helpful. For example, rural schools are almost inexistent. This is one of the main reasons for families to leave the rural area and only the older ones remain. The low educational level among the farmers is also one of consequences of it. In general, farmers need to be more motivated through the availability of services and federal incentives, such as the improvement of milk price.

**Regional Expertise:** Santo Antonio de Pádua

Date: 07 June 2018

Place: Office of the Municipal Secretary of Agriculture

Expert: Mr. Waldir Neto – Municipal Secretary of Agriculture

- *What is missing to ensure that people are better adapted to drought?*

What is missing is the concern with the rural producer. Authorities need to anticipate themselves so that they can provide better support to farmers. For example, at the moment I am responsible for smallholder farmers getting the services of farm tractors for plowing or support in digging up artificial ponds at subsidized prices, lower than the market prices.

- *What should be preventive measures to minimize losses due to droughts?*

Awareness raising among farmers should be enhanced. First, there is no sense of community. Producers are very individualistic. Second, there is the need of financial incentives. Credits for their development should be more available, as well as the need of technical assistance. EMATER needs more financial resources so that they can better support the producers in technical matters.

- *Are more policies needed? Or is it only a matter of implementing the existing ones?*

Yes, more policies are needed. Policies to ensure lower financial interests and the availability of financial funds for adaptation measures are needed. Also, capacity building for farmers is also needed for them to improve their farming techniques.

- *Do you believe a risk transfer mechanism such as insurance- based mechanisms would be feasible in the region?*

There is already a similar municipal mechanism that ensures the emergency support. For example, in the period of drought in 2017, a truck was made available through municipal funds to transport extra fodder and sugar cane bought for the farmers to cope with the drought.

**State Expertise:** Rio de Janeiro

Date: 03 July 2018

Place: Office of the Rio Rural Program Coordination

Expert: Ms. Helga Hissa – Rio Rural Program Coordinator

- *What is missing to ensure that people are better adapted to drought?*

It lacks the necessity of perceiving that it is a problem. And this means admitting that drought is a problem. There is a lack of planning due to the lack of capacity building in the area. Capacity building is needed to understand the interconnections and cause-effect problems. This is at all levels, the network connecting government, different actors and farmers have to be better prepared to deal with the cause-effect measures to minimize the impacts of climate change.

- *What should be preventive measures to minimize losses due to droughts?*

Capacity building to ensure that the adoption of adaptive measures is beneficial and needed. Also, the economic situation of each municipality has to be taken into consideration. The engagement of people is important. The interconnections among the different actors need to be sought and also the involvement of the private sector has to be developed. Involving the private sector is a way to ensure an alternative to the state in supporting actions to enhance the sustainability of rural producers. The Rio Rural Program has implemented some of the tools that will remain as legacy for future planning. The program, though financially supported by the state, now is looking for alternative partnerships to ensure its continuity.

- *Are more policies needed? Or is it only a matter of implementing the existing ones?*

More than policies, people need to be more engaged. Capacity building is necessary. For example, the EMATER technicians were oriented to show the farmers the interconnections, the necessity of one action in order to ensure that another was feasible. For example, if a farmer got the financial resource for a forage crop, technicians informed that if they eventually gave up having the forage crop, they would eventually be not resilient if a future drought hit.

- *Now that the Rio Rural Program is coming to an end<sup>8</sup>, how is it going to be?*

Partnerships are being sought. Also, there is the Agroecology State Plan under way and this plan will include a financial mechanism to enhance agroecological practices in the state.

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<sup>8</sup> The Rio Rural Program is planned to end in 2018. The last submission of projects for individual resources was in the first semester 2018.

**State Expertise:** Rio de Janeiro

Date: 04 July 2018

Place: Telephone interview

Expert: Ms. Olga Martins Wehb – Climate Change Superintendent of the Rio de Janeiro State Environmental Secretary

- *What is missing to ensure that people are better adapted to drought?*

There is the need of awareness raising and change in behavior. Otherwise it remains only as an academic document. There is the need of public policies to ensure environmental education and implementation of actions. In order to ensure education as priority for adaptation to climate change, public policies are needed.

- *What should be preventive measures to minimize losses due to droughts?*

There is a lack of collective effort to ensure that the network of stakeholders is active. This network involves the government, academia, NGOs and private sector.

- *Are more policies needed? Or is it only a matter of implementing the existing ones?*

The state has a fairly advanced legislation in the environmental area, regarding environmental licensing and ICMS ecológico<sup>9</sup>. Moreover, there is the Climate Change State Law of 2012 followed by the State Plan for Climate Change. The INEA<sup>10</sup> manages a project on emissions inventory and the FIOCRUZ<sup>11</sup> has conducted a health vulnerability mapping for climate change in the state. Many things have been done and these actions can all be considered measures for adaptation, but more policies are needed to ensure capacity building.

- *What are the specific actions for the adaptation to climate change in the state?*

For approximately one year the adaptation plan for the state have been discussed. It includes getting together different specialists from the areas of water resources, coastal management, health, green agenda and infra structure. Now this group will begin analyzing methodologies to refine modelling studies and problem evaluation for then begin to establish the needed measures for adaptation. The idea is to have the plan ready by the end of the year (2018).

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<sup>9</sup> ICMS ecológico: Legal mechanism, in which municipalities have access to more funds generated through the taxes over goods and services (ICMS), as long as they restrict land use in areas for the preservation of native vegetation. (Available at: <https://www.oeco.org.br/dicionario-ambiental/28048-o-que-e-o-icms-ecologico/> Accessed 13 August 2018)

<sup>10</sup> INEA: Instituto Estadual do Ambiente- State Environmental Institute, responsible for the protection, conservation and execution of environmental legislation in the state of Rio de Janeiro. (Available at: [http://www.inea.rj.gov.br/Portal/MegaDropDown/Institucional/O\\_que\\_e\\_o\\_Inea/index.htm?lang=](http://www.inea.rj.gov.br/Portal/MegaDropDown/Institucional/O_que_e_o_Inea/index.htm?lang=) Accessed 13 August 2018)

<sup>11</sup> FIOCRUZ: Fundação Oswaldo Cruz – Research institution managed under the Brazilian Ministry of Health that aims the promotion of public health. (Available at: <https://portal.fiocruz.br/fundacao> Accessed 13 August 2018)

**State Expertise:** Rio de Janeiro

Date: 10 July 2018

Place: Telephone interview

Expert: Mr. Nelson Teixeira –Executive Secretary of the Rio Rural Programme

- *What is missing to ensure that people are better adapted to drought?*

Producers need to believe that climate change is happening. They believe it is a religious event, so they are not aware that the implemented strategies must be kept. Over 30% of the producers in the state implemented measures through the Rio Rural program, the tendency is that other will follow and also implement such adaptive measures. If the bad practices have been disseminated along the years, now the good ones can also be spread out.

- *What should be preventive measures to minimize losses due to droughts?*

There is a lack of rural funding. For example, the Rio Rural Program demonstrated that social empowerment can be a process from bottom up. Now the concert is with the sustainability of these projects that have ensured this empowerment.

Work should be done in three different axis: first, the agro-credits from the National Ministry of Agriculture should also include measures for conservation and capacity building. By doing so, the funds could be optimized to ensure agro-production and environmental conservation. Second, the environmental funds are all directed to natural conservation units, and it is forgotten that in rural areas there is a tax of green conservation and restauration of up to 30% of the area. Farmers are a tool for environmental protection and public policies recognizing them as such are needed. Third, there is the need of enhancing partnerships with the private sector. A platform in which companies, through their social responsibility actions, could take part in projects that support environmental conservation is needed.

- *What is missing to ensure sustainability in the adaptation process and in the measures implemented through the Rio Rural Program?*

There is a gap in the technical capacity of EMATER's technicians. They went under capacity building programs to understand climate change and awareness raising. Though much of the needs have been fulfilled, the demand only grows. So, training programs are important for future. There are even municipal programs for them to get updated in latest practices and more complex ones. They are still very incipient due to the financial crisis in the state.



## National Expertise

Date: 27 July 2018

Place: Telephone interview

Expert: Prof. Dr. Carlos Nobre – Climatologist, Climate Change Researcher, member of the Brazilian National Council for Scientific and Technological Development (CNPq), President of the Directive Council of the Brazilian Panel on Climate Change<sup>12</sup>, IPCC research contributor.

- *Is there really climate change in Brazil or are the climate changes due to meteorological events that would happen anyway?*

We are going through global changes, however the changes at the micro level are more difficult to be identified. We cannot assume that all the changes on climate are due to natural variability. Everything indicates that it follows the predicted global tendency. It is difficult to prove the phenomenon, but it does not mean that changes will be extreme as predicted. Locally it is more difficult to predict as there can be specific variables that can influence the climate.

- *What is missing for us to better understand and predict the climate changes?*

At the moment we have a good forecast system for rapid onset events, for example hurricanes. This system needs to be improved. For this, monitoring systems have to be improved so that the forecasting system can also be improved.

The CEMADEN was created with this objective. One of its tasks is to work on the forecasting systems of the Northeast Semi-Arid region so that the economic collapse can be foreseen and avoided. After the water crisis in the Southeast region Brazil it began working on water availability. It is a matter of time until CEMADEN includes other natural events that affect survival and economic losses.

- *What is missing to ensure that people are better adapted to drought?*

We see that there is the need of more field studies, new and more resilient crop species need to be developed. In political terms, the agro-zoning has to be changed. For example, the Santa Catarina state will change it to tropical fruticulture. With climate change, tendency will be of a general change in agricultural areas. People take it as a joke, but in the future, Argentina will be a very good coffee arabica producer.

Most important, we need to avoid global warming. We are already out of limit and with this, we are already losing agricultural competitiveness in the global market.

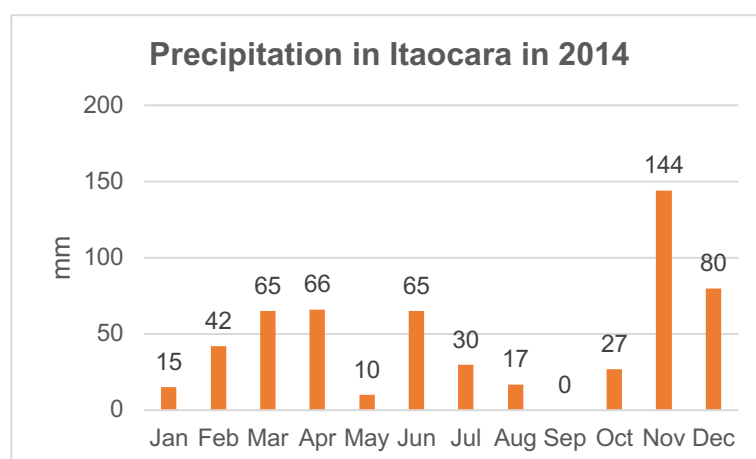
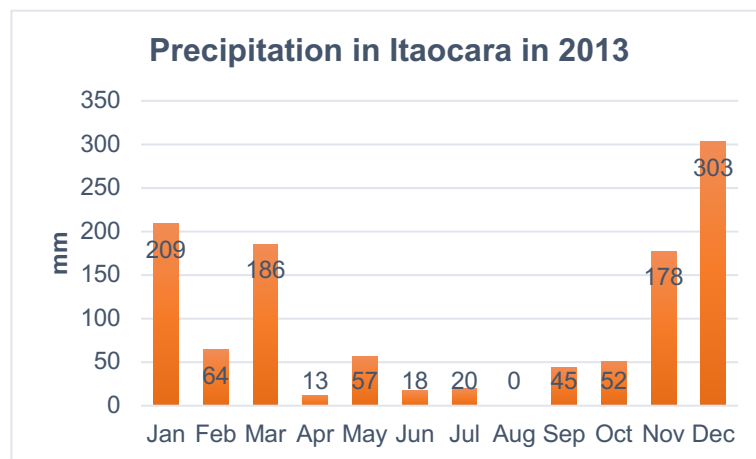
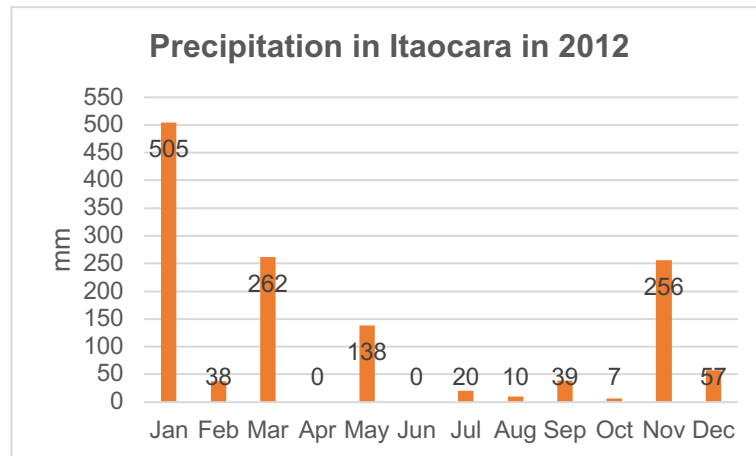
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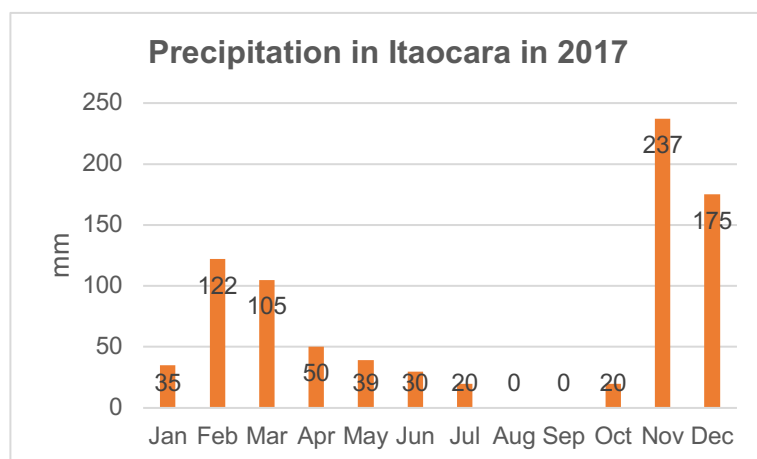
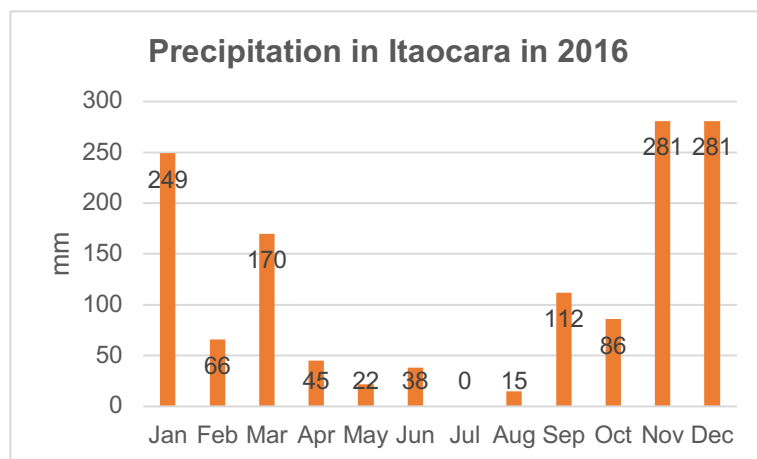
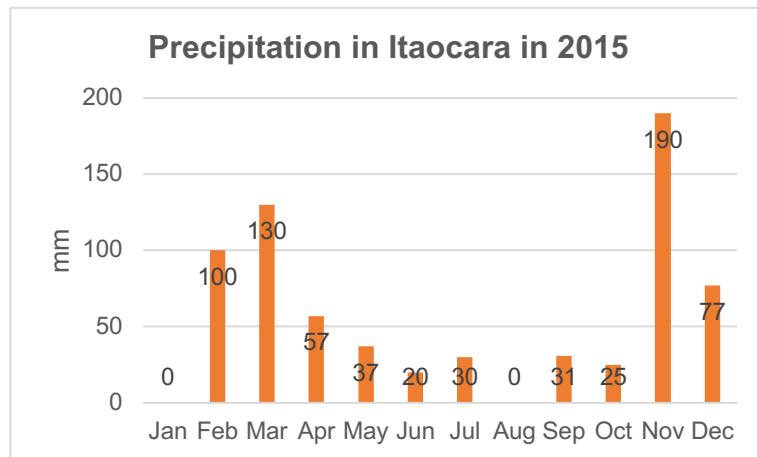
<sup>12</sup> PBMC: Painel Brasileiro de Mudanças Climáticas. The Brazilian national body that gathers scientific information relevant to climate change in the country. (Available at: <http://www.pbmc.coppe.ufrj.br/en/> Accessed 14 August 2018).

- *During my field work, I noticed that smallholder farmers are more prepared for coping with drought rather than adapting to it. Why is that so?*

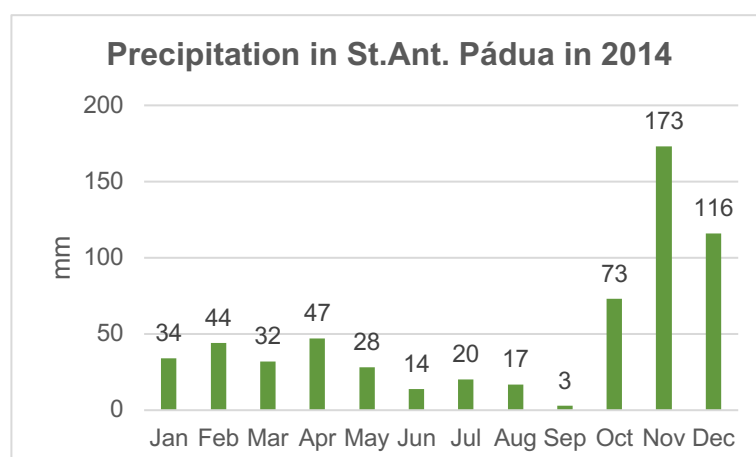
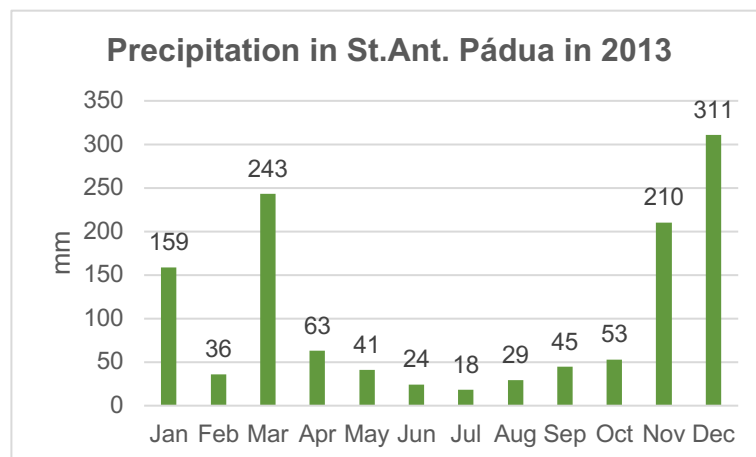
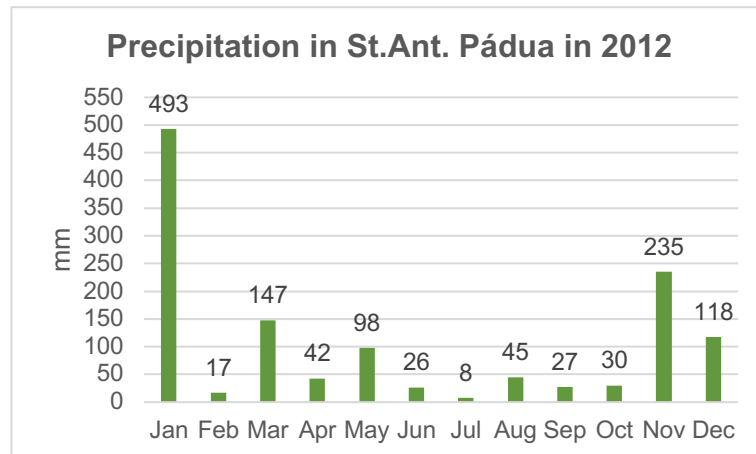
From my point of view, agriculture in Brazil is too close to economic and political interests. When there are losses, financing policies give a very short time for farmers to recover without charging them high interests. There is a silent dimension in the drought industry, there are no permanent interests in solving the problem due to political interests. Politicians implement short term measures to adapt. Then in the next mandate the next politician does not give continuity. At the end, adaptation becomes coping capacities. There is political obstruction to the adaptation to climate change.

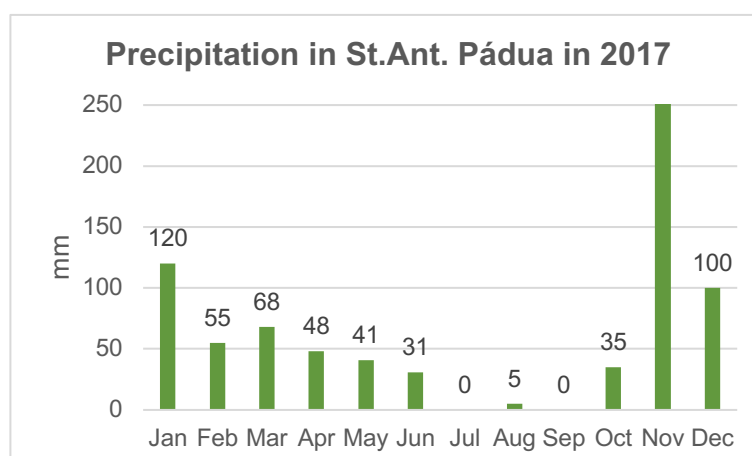
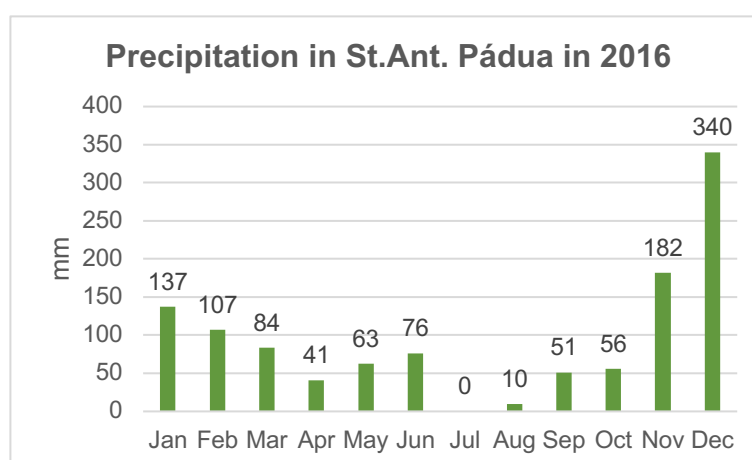
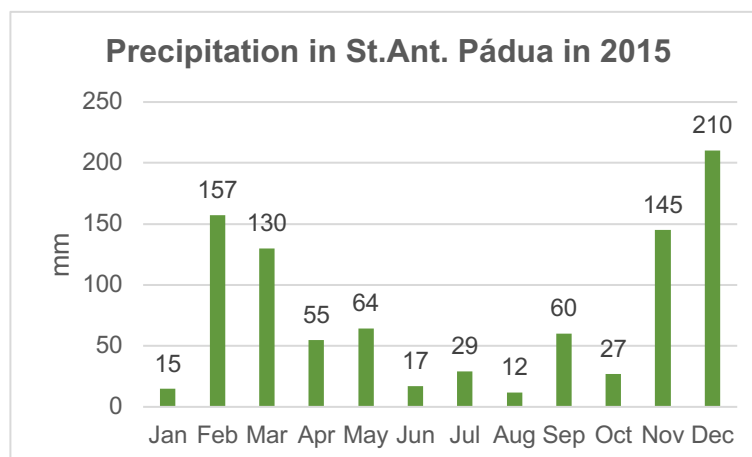
## 9.2 Precipitation Graphs from Records in Itaocara from 2012 to 2017





### 9.3 Precipitation Graphs from Records in St. Ant. de Pádua from 2012 to 2017





**Declaration in lieu of oath**

by

Cristina Hitoe Mergner

This is to confirm my Master's Thesis was independently composed/authored by myself, using solely the referred sources and support.

I additionally assert that this Thesis has not been part of another examination process.

Dinslaken, 14 September 2018

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Signature

